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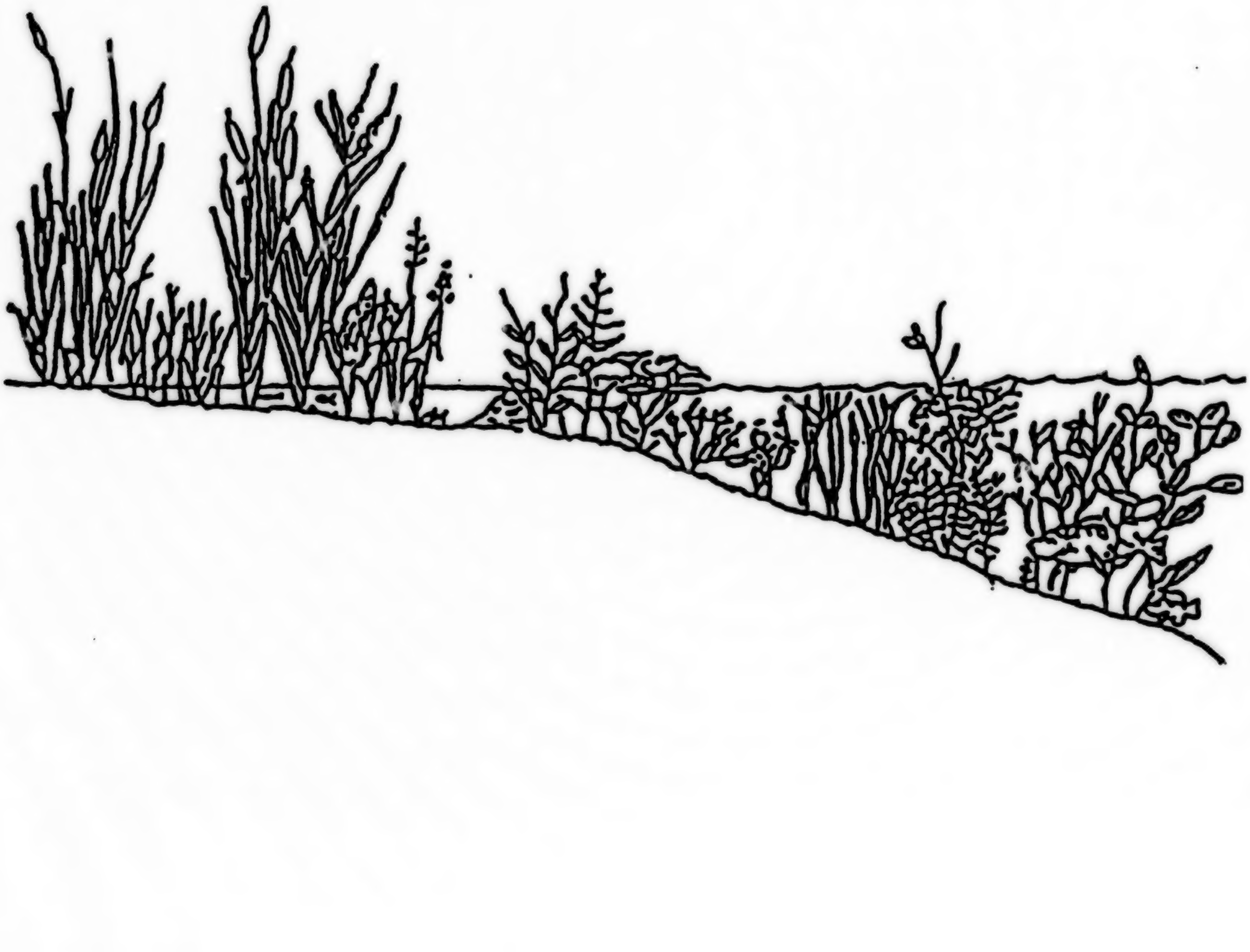
Long Term Resource Monitoring Program

Special Report

94-S005

Factors Limiting the Distribution of Larval and Juvenile Fishes

in Vegetated Habitats of the Upper Mississippi River



April 1994

95-036406

Factors Limiting the Distribution of Larval and Juvenile Fishes in Vegetated Habitats of the Upper Mississippi River

by

Michael R. Dewey and Cecil A. Jennings
National Biological Survey
National Fisheries Research Center
P.O. Box 818
La Crosse, Wisconsin 54650-0818

Prepared for

National Biological Survey
Environmental Management Technical Center
575 Lester Avenue
Onalaska, Wisconsin 54650

Project Leader: Steve Gutreuter

April 1994

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and sharing the biological information necessary to support the wise
stewardship of the Nation's natural resources.*

Preface

The Long Term Resource Monitoring Program (LTRMP) was authorized under the Water Resources Development Act of 1986 (Public Law 99-662) as an element of the U.S. Army Corps of Engineers' Environmental Management Program. The LTRMP is being implemented by the Environmental Management Technical Center (EMTC), an office of the National Biological Survey, in cooperation with the five Upper Mississippi River System states, Illinois, Iowa, Minnesota, Missouri, and Wisconsin, with guidance and program responsibility provided by the U.S. Army Corps of Engineers.

The mission of the LTRMP is to provide decision makers with information to maintain the Upper Mississippi River System as a viable large river ecosystem given its multiple-use character. The long-term goals of the program are to understand the system, determine resource trends and impacts, develop management alternatives, manage information, and develop useful products.

This report was prepared under Task PA(F)5, *Determine factors limiting fish populations*, as specified in the Operating Plan of the Long Term Resource Monitoring Program for the Upper Mississippi River System (USFWS 1988). The purpose of this study was to examine the importance of aquatic vegetation as habitat for larval and juvenile fishes in backwaters and to evaluate aerial videography to monitor vegetation types in backwaters.

This report was developed with funding provided by the Long Term Resource Monitoring Program.

This report was reformatted but otherwise printed as provided by the authors except for minor style changes. No additional review was performed by the Environmental Management Technical Center.

This report should be cited as:

Dewey, M. R., and C. A. Jennings. 1994. Factors limiting the distribution of larval and juvenile fishes in vegetated habitats of the Upper Mississippi River. Report by the National Biological Survey, National Fisheries Research Center, La Crosse, Wisconsin, for the National Biological Survey, Environmental Management Technical Center, Onalaska, Wisconsin, April 1994. EMTC 94-S005. Part I, 61 pp.; Part II, 19 pp.

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Part I: Gear Evaluation and Microhabitat Analyses

I. Gear Evaluation and Microhabitat Analyses

Summary

Using light traps, we studied the use that young fishes make of vegetated and nonvegetated habitats in Lawrence Lake (Pool 8, Upper Mississippi River). Habitat use was both extensive and variable. Fish were found in all portions of the macrophyte beds. Catches at the two vegetated sites were dominated by larval *Lepomis* spp., whereas larval cyprinids and brook silversides comprised 75% of the catch at the open water site. Backwater macrophyte beds both near to and distant from the main channel of the Mississippi River displayed similar patterns of habitat use. The open water site was used principally by gizzard shad and unidentified Cyprinidae. Habitat use in macrophyte beds with differing vegetation densities in Lawrence Lake was probably influenced by multiple factors. Physical and chemical microhabitat data explained little of the variation in catch in light traps. Two-stage sampling analyses indicated that when fish density is highly variable, sampling at many stations (one sample per station) is needed to assess habitat use in relation to vegetation density and species complexity.

We evaluated several gears for both quantitative and nonquantitative sampling of juvenile fishes in vegetated habitats. From July through September, we conducted field tests to compare catches from fyke nets, hoop nets, gill nets, and minnow traps. Three quantitative sampling gears, an electrofishing frame, a drop net, and a pop net, were used. The electrofishing frame was modified with a drop-net mechanism to assess the capture efficiency of the electrofishing device and to serve as a drop net.

Catches with all three quantitative gears were dominated by juvenile bluegills. The electrofishing frame caught significantly fewer fish in turbid vegetated areas than the drop and pop nets, due to difficulty in observing and netting stunned fish. Capture efficiencies with the electrofishing frame were higher in clear nonvegetated areas (mean 80%) than in turbid vegetated areas (mean 5%). The drop net and pop net yielded similar catches in number and species composition. With the drop net, extensive seining (8-10 hauls) was required to collect all fish within the net enclosure. However, use of a removal method to estimate absolute catch decreased seining effort to three or four hauls, more comparable to that of the pop net. We recommend either drop nets or pop nets for quantitative sampling.

Replicated tests with nonquantitative sampling gears were conducted to evaluate the effectiveness of fyke nets, hoop nets, small-mesh gill nets, and minnow traps in submergent vegetation and the effectiveness of small-mesh gill nets and hoop nets in an open water habitat. Of the nonquantitative gears tested, fyke nets produced the greatest numbers and species of fish. In open water, replicated sets of small-mesh gill nets and hoop nets showed that the gill nets were effective for capturing gizzard shad and golden shiners.

Introduction

Aquatic macrophytes in the Upper Mississippi River ecosystem are used by more than 80 species of fish for some habitat function (Janecek 1988).

Upstream of Pool 13, the river has large areas of water surface off the main channel and considerable rooted aquatic and wetland vegetation. Large beds of submergent aquatic vegetation have been quantified in Pools 7 to 9 (Gilbertson et al. 1981). The abundance of macrophytes is related to ecological characteristics of the backwater habitat, such as shallow depth (<1 m), the presence of fine-grained organic sediments, nutrient-rich waters, and slow current velocity (Peck and Smart 1986).

Submersed macrophytes influence dissolved oxygen concentration, transport nutrients from the sediments to the water column, and enhance sediment deposition (Carpenter and Lodge 1986). For fish, macrophytes provide feeding grounds as well as spawning, nursery, and protective habitats. Backwater habitats in the Upper Mississippi River contain the highest plant diversity and biomass and are important nursery areas for larvae and juveniles of nearly all fish species in the river (Schaeffer and Nickum 1986).

Habitat rehabilitation projects to modify existing backwaters and mitigation techniques to counter the effects of habitat degradation are being implemented on the river. Knowledge of the biotic and abiotic factors that contribute to the relative value of vegetated habitat of fish will enhance the success of such projects.

This study was designed to determine factors that limit the distribution and abundance of fishes in the Upper Mississippi River. The overall purpose of the study, initiated by the National Fisheries Research Center at La Crosse, was to develop and evaluate gear and methods for sampling larval and juvenile fishes in heavily vegetated backwater habitats. These methods were used to examine microhabitat requirements of young fishes and to identify potential factors that may limit fish populations in the river ecosystem.

The objectives of this study were to (1) evaluate gear for sampling larval and juvenile fishes in habitats of differing vegetation types and density, (2) evaluate the relationships between selected habitat characteristics and the distribution of larval and juvenile fishes, and (3) recommend methods and experimental design characteristics (numbers of sites and samples, etc.) necessary to evaluate the abundance of early life stages of fish.

Methods

Studies were conducted in Lawrence Lake (river mile 691), a shallow backwater lake situated in the lower portion of Pool 8 which receives water from the main channel of the Mississippi River (Fig. I-1). Substrates range from fine sand and silt to organic muck. The lake is shallow, with most depths <1.5 m. Aquatic macrophytes in the lake (Table I-1) are typical of those in other lentic areas of Pool 8.

Light Trap - 0.5-m Net Sampling

Replicated sampling with light traps was conducted at two vegetated sites, 800 m apart; one at the lower end of the backwater lake near the entrance to the main channel (site 1) and one at the upper end (site 2) (Fig. I-1). Samples were collected every 3 weeks from late May through mid-August (five sampling dates). Light trap sampling was conducted on two consecutive nights, with one vegetated site sampled each night. At each site, three stations representing vegetation types and densities within the macrophyte bed were sampled. These stations were located along a transect perpendicular from shore. The nearshore station was designated 1 EM or 2 EM (emergent), depending on the site, and was located 120-150 m offshore. The next station, 30 to 40 m further offshore, was designated 1 SN or 2 SN (submergent nearshore). The third vegetated station was designated 1 SO or 2 SO (submergent offshore) and was located 15-40 m further offshore. Vegetation at the nearshore EM stations was principally composed of pickerel weed (*Pontedaria cordata*) and coontail (*Ceratophyllum demersum*). Coontail and white water lilies (*Nymphaea tuberosa*) were dominant at the SN stations, and coontail and curlyleaf pondweed (*Potamogeton crispus*) usually dominated at the SO stations (Figs. I-2 and I-3).

An open water area (site 3) located near site 1 and about 200 x 600 m in size was also studied (Fig. I-1). Samples were collected in the middle of this open water area (station 3 OW) with both light traps and a 505-μm mesh 0.5-m conical plankton net. An impeller-type flowmeter was placed in the mouth of the plankton net to estimate the volume of water sampled. On each date site 1 was sampled, triplicate 3-min tows were made with the plankton net during the day and at night. After the nocturnal tows were completed, three light traps were placed at the open water site.

Light traps, described by Morgan et al. (in review), were primarily intended to sample larval fish, although the traps captured a few juveniles and adults. The traps, a modification of the Quatrefoil trap (Floyd et al. 1984), use chemical light sticks as a light source for attracting fishes. This design is based on a funnel-trapping system constructed from 6.4-mm plexiglass, where four 5-mm entrance slots allow fish to enter the inner chamber. Once the fishes are inside, escape through the narrow slot is difficult. Styrofoam floats were affixed to the top of the traps for floating them on the surface, and an anchor line was attached to the bottom plate. Triplicate sets were made at each station with traps set approximately 10 m apart. Light traps were set about 45 min after sunset and were fished for a 2-h period to standardize sampling effort. After this time period, we approached the light trap by boat, and a plankton net (505-μm mesh) was slowly positioned under the trap. The trap was washed several times to transfer the fish to the plankton net, where they could be collected in a bucket at the cod-end for transfer into a jar containing a 10% formalin solution.

All light trap and plankton net samples were sorted and identified in the laboratory. Twenty fish from each replicate sample were measured to the nearest 0.1 mm for length analyses. All individuals in these subsamples were classified by developmental stage: yolk-sac larva, protolarva, mesolarva, metalarva, juvenile, or adult (Snyder 1976). Catch in plankton nets was adjusted to numbers per 100 m^3 of water filtered. About 15% of the samples collected by light traps and 0.5-m nets were randomly selected for analysis of sorting efficiency. These samples were independently sorted by a second technician, and any specimens missed in the first sorting were enumerated and identified.

Biotic and abiotic parameters were described for all stations sampled. Vegetation biomass and species composition were measured by removing vegetation from the inside of a circular 0.2-m^2 enclosure randomly placed in three locations at each vegetated station. Each vegetation sample was separated by species, and the dry-weight biomass of each species was gravimetrically determined. Mean total biomass and mean biomass by species were calculated.

Dissolved oxygen, pH, conductivity, temperature, and turbidity were measured with a Hydrolab Model 4044 (Hydrolab Corporation, Austin, TX) and a field turbidimeter. Intermittent 24-h continuous measurements of water quality were also made with a Hydrolab data sonde. Two data sondes (one per station) were used, each suspended about 50 cm above the bottom. Since two stations could be monitored simultaneously, water quality measurements were made for 4 days each week sampling was conducted. A substrate sample was taken at each station to evaluate substrate type with particle size analyses. Sieving and weighing procedures followed those used by the U.S. Environmental Protection Agency and U.S. Army Corps of Engineers (Plumb 1981). Percent fine fraction (silt and clay) and coarse fraction (sand) was determined.

Evaluation of Quantitative Gear for Juvenile Fish

The effectiveness of three quantitative gears (electrofishing frame, drop net, and pop net) for sampling juvenile fishes in vegetated habitats was compared in monthly replicated tests during July, August, and September in the lower portion of Lawrence Lake. When possible, sampling with the three gear types was conducted on three consecutive days. Field tests were conducted in submergent macrophyte beds in 0.6- to 1.0-m-deep water with no discernible current. Turbidity readings ranged from 10 to 20 nephelometric units (NTU). The principal aquatic macrophytes present were coontail (*Ceratophyllum dermersum L.*) and water milfoil (*Myriophyllum* spp.), with total mean dry weight biomass ranging from 55 to 255 g/m^2.

The electrofishing frame, modified from that described by Bain et al. (1985), consisted of a 3.1-m-long x 1.8-m-wide x 1.2-m-high polyvinylchloride frame with an electrode wire attached 0.3 m above the bottom along the 3.1-m sides (Fig. I-4). The 3.1-m sides could be easily removed for transporting the gear in the field. The electrodes were constructed from RG-8U coaxial cable with the insulation removed in 18-cm sections every 20 cm. The electrodes were connected by 10-gauge multistrand wire to the booms of our electrofishing boat, which contained a 5.0-kW gasoline-powered generator that supplied 300 V and 6-8 amps of alternating current. Netting (6.4-mm mesh) with galvanized pipe held in a collar along the bottom was attached to the frame. The netting could be rolled up and held above the waterline by nylon rope attached to each corner and connected to a mechanical-release device

(Fig. I-4). When released, the netting would fall, functioning as a drop net. Three frames were set about 15-20 m apart and were left undisturbed for 30 min before the first frame was sampled. After sampling operations were completed for one frame, the electrodes on the next frame were connected to the electroshocker booms, and the area was left undisturbed for 30 min before the electroshocker was engaged. When used as an electrofishing device, the sampling operation usually required four people. Two persons on the electrofishing boat operated foot switches to control the power supply and observed the workers in the water. During sampling, the electrofishing boat was positioned about 25 m from the frame. Two people wearing chest waders remained 10 to 15 m from the frame until the power supply was activated. When the electrical field was activated, the two netters rapidly approached the frame and netted immobilized and floating fish within it. The generator remained on until all visible fish had been netted and the interior of the frame had been thoroughly inspected. Just before deactivation of the electrical field, the netting was released to enclose the frame, and the sides were checked to ensure that the pipes were resting on the bottom. Most of the vegetation was then removed from the interior of the frame, and repetitive seine hauls were made to remove any remaining fish. For each seine haul, the entire length of the enclosure was seined with a 1.8-m net (6.4-mm mesh), keeping the brails against the wall of the netting. The catch in each haul was counted, and individual lengths (mm) of fish were recorded. We terminated seining in the enclosure when three consecutive hauls produced one or no fish per haul, and assumed that all fish in the enclosure had been collected. Sampling efficiency for electrofishing was then calculated as the percentage of fish collected while the power supply was engaged.

Additional field tests were conducted in September to compare efficiency of the electrofishing frame in vegetated and nonvegetated habitats. Three replicated tests were conducted at the National Fisheries Research Center in a nonvegetated pond containing fathead minnows (*Pimephales promelas*). Water depths ranged from 0.7 to 0.9 m, and turbidity readings ranged from 2.0 to 3.0 NTU. At the Genoa National Fish Hatchery, a replicated test was conducted in a heavily vegetated pond (mean total dry weight biomass 380 g/m^2) having relatively clear water (turbidity 3.5 NTU) and a variety of fish species. Sampling procedures were the same as those used at Lawrence Lake.

The electrofishing frame was also tested without the power supply, as a drop net enclosing a 5.6-m^2 area. Frames were set 15-20 m apart at a site and were simultaneously released with a 25-m cord after being undisturbed for 30 min. After most of the vegetation within the enclosure had been removed, repetitive seine hauls were made to collect the fish inside the enclosure. The catch in each seine haul was enumerated, and individual lengths (mm) of fish were recorded. When one or no fish was collected on each of three consecutive hauls, sampling operations for that drop net were terminated, typically after 8 to 10 seine hauls. We also used the Zippin (1958) removal method to estimate catch within the drop-net enclosure from catch data obtained in three or four seine hauls. This is a multinomial method that (with the aid of prepared charts) allows for a very rapid estimate of population size.

The same sampling design was used for pop nets, with three nets set 15-20 m apart and released simultaneously after 30 min. After the pop net was released, the bottom sections were pursed together to enclose the catch. The top frame and netting were placed on a portable stand nearby in the water for removing fish. Because the area sampled (5.6 m^2) was the same for each of the three gear types, catch per unit effort (CPUE) was directly comparable.

Evaluation of Non-Quantitative Sampling Gear for Juvenile Fish

Field tests were conducted in Lawrence Lake in July, August, and September to evaluate the relative effectiveness of various gears for sampling juvenile fish. Monthly tests of small-mesh gill nets began in July, hoop nets and minnow traps were added in August, and fyke nets were added in September (Table I-2). Triplicate sets of each gear type, except minnow traps, were made from 0800 to 2000 h and from 2000 to 0800 h to evaluate diel variation in catch in both emergent and submergent vegetation. Tests were conducted at site 1 and at the open water site with gill nets and hoop nets. Hoop nets were 1.2 x 0.5 m with tarred nylon netting of 3.2-mm bar mesh. Gill nets used in July consisted of two 12.2-m-long and 1.2-m-high panels, one of 9.5-mm bar mesh (#69 monofilament) and one of 15.9-mm bar mesh (#139 monofilament). In August and September, two gill nets were sewn together to produce a 24.4-m-long net with four panels, two of small mesh and two of larger mesh. Water quality and vegetation biomass were monitored during each monthly collection with methods used in the other gear evaluation studies.

In August and September, we sampled with six minnow traps attached to a 3.2-mm mesh block seine, 4.9 m long x 1.2 m high. The minnow traps were attached in pairs on opposite sides of the net, two at the center and two situated 0.6 m from each end of the net. All traps were 0.3 m above the bottom. Two poles, one on each end of the block seine, were driven into the substrate to support the net and minnow traps. Each minnow trap was 0.4 m long, constructed of galvanized hardware cloth of 6.4-mm mesh. Catches from all six traps were combined and considered as one sample.

In September, we used small fyke nets, 1.3 m long x 0.6 m high, with a 4.7-m lead and 3.2-mm tarred nylon bar mesh. These fyke nets are the same as those used in the LTRMP fish monitoring studies. The fyke nets were used in conjunction with hoop nets, minnow traps, and gill nets in submergent and emergent vegetation, using the same sampling design as in July and August. In addition, triplicate 24-h sets were made to compare the catches of fyke nets, hoop nets, and minnow traps set in submergent vegetation. Triplicate fyke and hoop net sets were made daily for three consecutive days (nine replicates). Since only one set of minnow traps was available, one replicate was set each day for three consecutive days.

Statistical Analyses

Analysis of variance (ANOVA) was used to evaluate statistical differences in catch among sites and stations. Catch data were tested for normality; we either logarithmically transformed the data before ANOVA or used the non-parametric Wilcoxon ranked sum test, as appropriate. A percent similarity index (Whittaker and Fairbanks 1958) was used to compare species composition of catches with the 0.5-m plankton net and light traps at the open water site and to compare the overall species composition of the catch between sites. A two-stage sampling analysis was used to estimate the numbers of stations and subsamples (within a station) within a backwater area needed to provide density estimates within 20% of the true mean with 95% confidence (Snedecor and Cochran 1967). This analysis was performed on catch data in mid-June, when total catch was greatest. All analyses were performed with PC-SAS (SAS Institute, Inc. 1987), and a Type I error (α) of 0.05 was used to evaluate the significance of statistical tests.

For light-trap and 0.5-m plankton net samples, 19 (13%) of the 150 total samples sorted were randomly selected for reexamination, to estimate sorting efficiency. Of the 5,530 fish sorted, only 12 (0.2%) were missed during the initial examination of samples (Table I-3).

Results

Gear Evaluation

Larval fish sampling. Fish taxa collected during the entire study are listed in Table I-4. The light trap catch was partitioned into 14 taxa representing seven families and six developmental stages (Table I-5). The maximum catch per light trap was 832 fish.

We compared catches in light traps and 0.5-m plankton nets at the open water site. Similarity in catch was low throughout the study, except on July 30, when larval cyprinids dominated the catch with both gears (Table I-6). No fish were caught at night with either gear type during the sampling performed on May 30. During periods of peak abundance of larval gizzard shad, total catch (all taxa) and the catch of gizzard shad were consistently greater with the 0.5-m net. Light traps were consistently more effective for only one taxon, the brook silversides. The mean length of gizzard shad in samples was greater with the 0.5-m plankton nets than with the light traps, but mean lengths of the other principal taxa were similar in catches of the two gears (Table I-7).

Quantitative sampling of juvenile fish. Juvenile centrarchids dominated the catch with all three gears, but drop nets and pop nets captured many more fish and taxa than the electrofishing frame (Table I-8). Based on length-frequency data and growth data for bluegills in the Mississippi River (Carlander 1977), most centrarchids in the samples taken were young-of-the-year. Total catch with the electrofishing frame was significantly less than that with each of the two other gears, whereas total catch did not differ between pop nets and drop nets. Mean length and size range of fish captured were generally similar for the three gears tested (Table I-9).

Eight to 10 seine hauls inside the enclosed drop net were usually required to remove fish from the enclosed net. When the Zippin (1958) removal method was used to estimate catch with the drop net, only three or four seine hauls were required, a 40% to 50% reduction in seining. Average catch estimates were within 12% of the actual catch when calculated with only three seine hauls (Table I-10). For two replicates, total catch for the first three hauls remained relatively high. For these two samples, estimates calculated with four seine hauls averaged within 6% of actual catch. When estimating catch with four seine hauls for all tests, average estimates were within 5% of the actual catch.

Capture efficiency of the electrofishing frame (the percentage of fish within the enclosure collected while the electroshocker was engaged) was significantly lower in vegetated habitats than in nonvegetated habitats. Mean capture efficiency ranged from 0% to 11% in vegetated areas and from 60% to 91% in nonvegetated areas (Table I-11).

Non-quantitative sampling of juvenile fish. Fish abundance and species composition of the catch differed among gill nets, hoop nets, fyke nets, and minnow traps. Our sampling effort with fyke nets was less than that with the other gears (Table I-2), yet the fyke nets captured nearly as many species as the gill nets and caught more than the hoop nets and minnow traps (Table I-12). During September, when all four gears were compared, total catch and species richness were greatest with fyke nets in both emergent and submergent vegetation during both day and night (Table I-13). The mean total catch of fyke nets was significantly greater than that of the other gears in both 12-h and 24-h sets (Fig. I-5). The total catch with the gill nets, hoop nets, and minnow traps did not differ between day and night. In contrast, fyke nets caught more fish at night in emergent vegetation and more fish during the day in submergent vegetation (Table I-13). The total catch with gill nets was greater at the open water station than at the two vegetated stations, where catch did not differ between stations. With hoop nets, total catch differed among all three habitats and was greatest in the emergent vegetation. Total catch in minnow traps was greater in emergent vegetation than in submergent vegetation. The number of taxa collected with each of the four gears in vegetated habitats was usually similar during day and night sampling (Table I-12).

Species composition of the catch with hoop nets, minnow traps, and fyke nets was similar during both day and night sampling. The catch was principally comprised of juvenile bluegills and warmouth (Table I-14), dominated by juveniles <45 mm total length (Figs. I-6 and I-7). In vegetated habitats, fyke nets caught more taxa than the other gears (Table I-12). The catch in gill nets in the open water habitat was primarily gizzard shad and golden shiners (Table I-15). Only four fish, all bluegills, were caught with hoop nets at the open water site.

In 24-h sets in September, total number of fish caught and species richness of the catch were highest with fyke nets (Fig. I-5 and Table I-16). Fyke nets caught 11 species from six families, dominated by juvenile centrarchids and pugnose minnows (Table I-16). Adult fishes captured in fyke nets were largely black crappie and common carp. [illegible] species caught with fyke nets were not captured by either hoop nets or minnow traps.

Habitat Use

Habitat description. The range of water temperatures, pH, and conductivity while sampling was relatively small, whereas dissolved oxygen and turbidity varied among stations (Table I-17). Diel fluctuations in water quality occurred at all stations throughout the sampling season (Figs. I-8 to I-12). The open water site was stratified through mid-June with water temperatures 6-8 °C less in the lower stratum (about 2 m deep) than those at the shallower vegetated sites (Figs. I-8 and I-9). Diel fluctuations in dissolved oxygen and pH were greatest from mid-June through July. By late August, diel fluctuations in dissolved oxygen, pH, and water temperature were relatively small, and dissolved oxygen levels at all stations were consistently <4 mg/L (Fig. I-12).

Vegetation biomass and diversity differed both spatially and temporally among the vegetated stations (Table I-18). Mean dry-weight biomass ranged from 78.7 to 441.8 g/m^2. Pickerel weed was the dominant emergent species at both sites, while coontail was the principal submergent macrophyte (Figs. I-2 and I-3).

Temporal and spatial differences. A total of 5,530 fish from seven families was caught in light traps; 95% of these fish were larvae. Catches at the two vegetated sites were numerically dominated by larval *Lepomis* spp. (88% and 97%), whereas larval cyprinids and brook silversides composed 75% of the catch at the open water site (Table I-19). The similarity of the composition of the catch at the two vegetated sites was 91% during the study year, while catch composition similarity at the lower vegetated site and the open water site was only 8.8%. The total catch at the vegetated stations was dominated by *Lepomis* spp. except for submergent offshore station 1 SO, where common carp and brook silversides were most abundant (Table I-20).

Temporal and spatial differences existed among sites and stations throughout the sampling season. The catch at the two vegetated sites was highest in mid-June and declined consistently through mid-August (Tables I-21 and I-22). Overall seasonal patterns of catch among taxa were similar at the two vegetated sites (Fig. I-13). The peak catches in mid-June were mainly due to the large catches of *Lepomis* spp. at the emergent and submergent nearshore stations. Densities of common carp and golden shiners, collected mainly in mid-June, were greater at the lower vegetated site (site 1) than at the other sites.

The seasonal pattern of catch at the open water site differed from that at the vegetated sites (Fig. I-14). Total catch at the open water site was relatively low until early July and thereafter remained relatively constant throughout the study (Table I-21). Catch of unidentifiable Cyprinidae, the principal taxon collected at the open water site, peaked in late July (Table I-22).

Analyses of total catch with light traps of the two principal taxa (*Lepomis* spp. and unidentifiable Cyprinidae) indicated variation among sites and stations. Total catch did not differ among sites, whereas the catches of *Lepomis* spp. and unidentifiable Cyprinidae did (Table I-23). Mean catch of

Lepomis spp. was greatest at the two vegetated sites, but the catch of *Lepomis* spp. at the lower vegetated site and the open water site did not differ, presumably due to the high variation in catch among replicates. The mean catch of unidentifiable Cyprinidae was greatest at the open water site. Mean total catch did not differ among station types, emergent, submergent offshore, submergent nearshore, and open water; however, the mean catch of *Lepomis* spp. and unidentifiable Cyprinidae did (Table I-23). Mean catches of *Lepomis* spp. were similar at the emergent- and submergent-nearshore stations, while no differences were found between the submergent-offshore and open water stations, where mean catches were lowest. In contrast, mean catch of unidentifiable Cyprinidae was greater at the open water station than at the vegetated stations. Temporal differences between stations did exist in total catch, catch of *Lepomis* spp., and unidentifiable Cyprinidae among the periods sampled (Table I-24). The catch of *Lepomis* spp. was correlated with vegetation richness or the number of plant taxa present ($r = 0.21$, $P = 0.034$), whereas the catch of unidentifiable Cyprinidae was negatively correlated with vegetation biomass ($r = -0.27$, $P < 0.01$) and vegetation richness ($r = -0.24$, $P = 0.014$). However, these variables accounted for little of the variation in catch.

Although a variety of developmental stages were caught, catches were usually dominated by protolarvae and mesolarvae (Table I-25). Most gizzard shad, collected mainly at the open water site, were mesolarvae or metalarvae. Brook silversides were usually captured as juveniles or adults.

Diel and seasonal differences in use of the open water site were noted (Table I-26). Catches were relatively small until late June, when night catches were highest and were dominated by gizzard shad, common carp, and *Lepomis* spp. In July, catches were composed largely of larval gizzard shad and unidentifiable Cyprinidae during both day and night sampling. In August, mainly cyprinids were caught (Fig. I-15). Interspecific differences occurred in diel catch; gizzard shad catches were larger at night, while more cyprinids were collected during the day. No diel differences existed in catches of either taxa ($P = 0.11$ for gizzard shad and 0.99 for unidentifiable Cyprinidae).

Effects of variability on density estimates. High variability in total catch among stations indicated the need for extensive sampling to obtain precise density estimates of fishes. During our study, stations often yielded dissimilar total catches, even for stations of a given vegetation type (i.e., emergent). Generally, variation among stations within Lawrence Lake exceeded that among replicate samples taken at a given station. Based on the two-stage sampling analysis conducted in mid-June, greater effort should be allocated to more stations rather than to more replicates per station. Analysis of means and variances for mid-June, when total catches were greatest, indicated that only one replicate per station would have to be collected. However, analyses indicated that 183 stations would have to be sampled to provide density estimates within 20% of the true mean.

Discussion

Difficulties in sampling small fishes in aquatic vegetation have hampered ecological studies of the early life stages of fishes (Kahl 1963; Higer and Kolopinski 1967). Larval fishes have been sampled in aquatic vegetation using pumps (Paller 1987), towed plankton nets (Conrow et al. 1990), and drop-boxes (Scott 1988). However, our success with towed nets in aquatic vegetation has been unsatisfactory. Clogging of the mouth of the towed net by aquatic macrophytes reduced catch and precluded the use of a flowmeter for quantitative sampling; therefore, we have evaluated light traps for sampling larval and (to a limited extent) juvenile fishes in aquatic vegetation.

The light trap has both positive and negative attributes as a sampling gear. The major criticism of the light trap relates to its species and size selectivity (Gregory and Powles 1988) because the behavioral response of individuals to the trap can change with ontogeny (Girsa 1969; Bulkowski and Meade 1983) or light-source intensity (Woodhead 1956). Conrow et al. (1990), who studied the distribution of larval fish in a Florida lake dominated by aquatic macrophytes, found that a towed net captured more fish and slightly more species than the light trap; however, the light trap was more effective in capturing the smaller larvae. Light traps are now being used successfully in sampling larval fish within vegetated habitats in rivers and reservoirs of the southeastern United States (Bob Wallus and Jack Kilgore, personal communication). As many as 10,000 larval fish have been collected in a single light trap. Gregory and Powles (1988), who compared the relative selectivities of light traps and Miller high-speed samplers, found that the length distribution of the ichthyoplankton was better approximated with light traps. They concluded that light traps and other passive devices were often the only way to sample physically obstructed, shallow waters. We believe that light traps are an effective sampling device for sampling heavily vegetated backwater areas in the Upper Mississippi River, with catch reflecting seasonal patterns of habitat use at various levels of vegetation density. Additional field trials should be conducted in early spring to evaluate light traps using chemical light sticks for sampling species, such as northern pike (*Esox lucius*), that use heavily vegetated backwaters.

The difficulty in obtaining quantitative fish samples from areas with dense submerged aquatic vegetation has led fishery biologists to underestimate the importance of these habitats as nursery and feeding areas (Heck and Thoman 1984). For sampling this habitat type, the pop net and drop net were the more efficient of the three quantitative gears that we evaluated. The electrofishing frame was inefficient due to our inability to locate fish in the turbid water and vegetation after the frame had been electrified.

Serafy et al. (1988) concluded that pop nets are well suited for quantitative sampling of small fishes in submerged aquatic vegetation and are relatively easy to assemble and operate, but they do have limitations. Since a relatively small area is sampled with the pop net, diversity values are lower than those estimated with seining or electrofishing; therefore, Serafy et al. (1988) recommended that multiple sub-samples be taken to increase the total area sampled. Dewey et al. (1989) reported that pop nets caught fewer species than seines in submergent vegetation due to the smaller area sampled;

however, the species not present in the pop net catch were obtained in very low numbers with a seine.

The drop net was nearly as efficient as the pop net, but extensive seining involving much time and effort was required to remove all fish from the enclosure. However, use of only three to four seine hauls with the removal method by Zippin (1958) to estimate catch substantially reduced effort. Although the drop net and pop net can be disassembled for transport, the pop net can be hauled in a boat fully assembled. The drop net is easy to assemble in the field, requiring only about 5 to 10 min, and can also be used as an electrofishing frame.

Of the gears evaluated, the fyke net was best for non-quantitative sampling of juvenile fishes in vegetated habitats. Although replicated evaluation was limited for all gears, the fyke net caught higher numbers and more taxa of juvenile fish than the other gears tested. The small-mesh gill nets seemed to be more effective than hoop nets in open water for sampling species such as gizzard shad and golden shiners.

Young fish extensively use aquatic macrophytes in swamps (Paller 1987), lakes (Conrow et al. 1990), and rivers (Scott and Nielsen 1989). Aquatic macrophyte beds were heavily used by larval and juvenile fishes in Lawrence Lake. Light trap catches at vegetated sites in Lawrence Lake were dominated by *Lepomis* spp. Similar results have been reported for backwaters in the Kanawha River, West Virginia (Scott and Nielsen 1989). Larger larval *Lepomis* and juveniles migrate into shallow water with submergent and emergent vegetation (Hall and Werner 1977; Paller 1987). We monitored use of the vegetation beds only at night, but these habitats are also used extensively during the day (Paller 1987). Paller (1987) noted that taxa including sunfishes, minnows, and darters tended to drift in the open channels at night. However, we caught few sunfishes during both day and night in open water habitat; rather, that habitat was used largely by larval gizzard shad and cyprinids. Paller (1987) also noted that CPUE was lower in the macrophyte bed:open channel interface than inside the macrophyte bed. Our catch at station 1 SO, located near the open water site, generally suggested this pattern of habitat use.

The use of macrophytes beds with varying vegetation densities in Lawrence Lake was presumably influenced by a variety of factors. Submersed aquatic vegetation influences fish distribution and abundance by creating structurally complex habitats (Crowder and Cooper 1979) that provide food and shelter (Barnett and Schneider 1974). Fish standing stocks can be strongly correlated with plant biomass (Stoner 1983; Robertson 1984). However, total catch in our light trap sampling was not correlated with plant biomass. Conversely, our catch of larval cyprinids, greatest at the open water site, was negatively correlated with both vegetation biomass and richness. The catch of *Lepomis* spp. was significantly correlated with vegetation richness. Poe et al. (1986), who compared the fish assemblages in altered and unaltered littoral habitats, found that vegetation richness and abundance had the most influence on fish community structure in both areas; their catch was composed primarily of young-of-the-year and yearlings. Eadie and Keast (1984) found that macrophyte diversity had a greater influence on fish species diversity than did the amount of vegetation cover.

Diel monitoring indicated both diel and seasonal variability in water quality. Metabolism of macrophytes and associated microflora, as well as open water phytoplankton populations, influence diel patterns of dissolved oxygen and pH (Ondok et al. 1984). Dissolved oxygen levels in Lawrence Lake were generally above 3 mg/L until mid-July. Eipper (1975) noted that dissolved oxygen concentrations above 3 mg/L seem to be safe for largemouth bass *Micropterus salmoides* and smallmouth bass *M. dolomieui* that had reached the free-swimming stage. Kramer and Smith (1962) reported that largemouth bass fry withstood "short-term" oxygen declines to 1 mg/L in midsummer with no apparent mortality. Our catches of larval fish in Lawrence Lake were relatively low at the vegetated stations in July and August, possibly due to low dissolved oxygen concentrations.

Use of both vegetated and nonvegetated habitats in Lawrence Lake by young fishes was both extensive and variable. All portions of the macrophyte beds were used, regardless of vegetation density or diversity. Furthermore, macrophyte beds near the mouth of the lake and beds in the inner portion of the backwater had similar patterns of use by fish. Two-stage sampling analyses indicates that extensive sampling at many stations would be needed to quantify fish abundance in this habitat type, characterized by high variation in fish densities. In larval fish studies, the expenditures of time and effort are greatest for the sorting and identification of samples, not for sampling.

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Table I-1. Aquatic vegetation collected in Lawrence Lake (Pool 8, Upper Mississippi River) in 1990, during sampling for larval and juvenile fish.

Scientific name	Common name
Potamogeton zosteriformis	Flatstem pondweed
P. crispus	Curlyleaf pondweed
P. pectinatus	Sago pondweed
Ranunculus tricophyllus	Collapsing white water buttercup
Myriophyllum spp.	Water milfoil
Ceratophyllum demersum	Coontail
Utricularia vulgaris	Common bladderwort
Heteranthera spp.	Water stargrass
Elodea canadensis	Elodea
Nelumbo lutea	American lotus
Nuphar advena	Spatterdock
Nymphaea tuberosa	White water lily
Sagittaria rigida	Arrowhead
Pontedaria cordata	Pickerel weed

Table I-2. Summary of sampling frequency, habitats sampled, and duration of set by gear type in evaluations of nonquantitative sampling gears in Lawrence Lake (Pool 8, Upper Mississippi River) in 1990.

Gear	July	August	September
Gill net	OW, EM, SUB	OW, EM, SUB	OW, EM, SUB
	12 h	12 h	12 h
Hoop net	--	OW, EM, SUB	OW, EM, SUB
	--	12 h	12 h, 24 h
Minnow trap[a]	--	EM, SUB	EM, SUB
		12 h	12 h, 24 h
Fyke net	--	--	EM, SUB
			12 h, 24 h

[a] Replicated sampling was conducted only on 24-h sets in September.

OW = open water, EM = emergent vegetation, SUB = submergent vegetation

Table I-3. Efficiency of ichthyoplankton recovery during sorting of samples collected.

Sample number (date/station-rep)	Number of fish in sample	Number of fish missed	Percent missed
053090/1EM-1	2	0	0
053090/1O-3 Day	2	0	0
061890/1EM-1	453	0	0
061890/1SN-2	74	0	0
061890/1EM-3	320	0	0
061890/1SN-1	372	0	0
061890/1EM-2	472	0	0
061890/1SO-2	27	0	0
061890/1SO-1	35	0	0
061890/1SO-3	21	0	0
061990/2SN-1	832	0	0
061990/2SO-3	5	0	0
061990/2SN-3	686	0	0
061990/2EM-1	238	8	3.4
061990/2SN-2	523	0	0
061990/2SO-1	21	0	0
061990/2EM-3	343	0	0
073090/1O-3 Night	92	2	2.2
073090/1O-1 Day	128	1	0.8
073090/1O-2 Day	155	1	0.2
Mean	240	0.6	0.3
Range	2-686	0-8	0-3.4

Table I-4. List of fishes collected in Lawrence Lake (Pool 8, Upper Mississippi River) in 1990.

Family	Scientific name	Common name
Lepisosteidae	*Lepisosteus osseus*	Longnose gar
Amiidae	*Amia calva*	Bowfin
Clupeidae	*Dorosoma cepedianum*	Gizzard shad
Esocidae	*Esox lucius*	Northern pike
Cyprinidae	*Cyprinus carpio*	Common carp
	Notimigonus crysoleucas	Golden shiner
	Notropis atherinoides	Emerald shiner
	N. emiliae	Pugnose minnow
	Notropis spp.	Minnows
	Cyprinidae	Unidentifiable cyprinids, excluding common carp
Catostomidae	*Minytrema melanops*	Spotted sucker
Ictaluridae	*Ictalurus natalis*	Yellow bullhead
	Noturus gyrinus	Tadpole madtom
Atherinidae	*Labidesthes sicculus*	Brook silversides
Percichthyidae	*Morone chrysops*	White bass
	Morone spp.	Temperate basses
Centrarchidae	*Micropterus salmoides*	Largemouth bass
	Lepomis gulosus	Warmouth
	L. gibbosus	Pumpkinseed
	L. macrochirus	Bluegill
	Lepomis spp.	Sunfishes
	Pomoxis annularis	White crappie
	P. nigromaculatus	Black crappie
	Pomoxis spp.	Crappies
Percidae	*Percina* spp.	Darters
Sciaenidae	*Aplodinotus grunniens*	Freshwater drum

Table I-5. Taxa and developmental stages of fishes collected during light-trap sampling in Lawrence Lake, Pool 8, Upper Mississippi River (1 = present in catch, 0 = absent in catch).

Taxa	Developmental stage					
	Adult Fish	Proto-yolk	Protolarval	Mesolarval	Metalarval	Juvenile
Clupeidae						
Gizzard shad	1	1	1	1	1	0
Cyprinidae						
Common carp	1	1	1	0	0	0
Golden shiner	0	1	1	1	0	0
Minnows (Notropis spp.)	0	0	0	0	1	0
Emerald shiner	0	0	0	0	1	1
Unidentifiable Cyprinidae[a]	0	1	1	1	1	0
Atherinidae						
Brook silverside	1	1	1	1	1	1
Percichthyidae						
Temperate basses (Morone spp.)	0	0	1	1	0	0
Centrarchidae						
Largemouth bass	0	1	1	0	0	0
Warmouth	0	0	0	0	1	0
Bluegill	0	0	0	0	1	0
Sunfishes (Lepomis spp.)	0	1	1	1	1	0
Crappies (Pomoxis spp.)	0	1	0	1	0	0
Percidae						
Darters (Percina spp.)	0	0	0	1	0	0
Sciaenidae						
Freshwater drum	1	0	1	0	0	0

[a] This grouping includes larval cyprinids (except common carp) that could not be further identified.

Table I-6. Mean percentage composition of catch and total number caught by gear type and percent similarity index for night samples from the open water site in Lawrence Lake (Pool 8, Upper Mississippi River).

	June 18		July 9		July 30		August 20	
Taxa	Plankton net	Light trap	Plankton net	Light trap	Plankton net	Light trap	Plankton net	Light trap
Clupeidae								
Gizzard shad	67	0	98	35	2	3	10	0
Cyprinidae								
Common carp	12	60	0	0	0	0	0	0
Emerald shiner	0	20	0	2	0	0	3	15
Unidentifiable Cyprinidae[a]	1	0	2	19	98	92	73	21
Atherinidae								
Brook silverside	0	7	0	42	0	5	7	63
Percichthyidae								
Temperate basses (*Morone* spp.)	3	7	0	0	0	0	0	0
Centrarchidae								
Bluegill	0	0	0	0	0	0	7	0
Sunfishes (*Lepomis* spp.)	13	0	<1	2	0	0	0	0
Percidae								
Darters (*Percina* spp.)	1	0	0	0	0	0	0	0
Sciaenidae								
Freshwater drum	3	7	<1	0	0	0	0	0
Mean total catch	100	5	301	17	278	20	14	17
Percent similarity in catch between gears	18		37		94		32	

[a] This grouping includes larval cyprinids (except common carp) that could not be further identified.

Table I-7. Total lengths and mean numbers of principal taxa of larval fishes caught per light trap or net tow (fish/100 m^3 of water filtered) at the open water site in Lawrence Lake (Pool 8, Upper Mississippi River).

Taxa	Sampling date	Light trap			0.5-m net		
		Total length (mm)		Mean catch per light trap	Total length (mm)		Mean catch per 100 m^3 of water filtered
		Mean	Range		Mean	Range	
Clupeidae							
Gizzard shad	June 18	--	--	0	6.1	3.3-16.5	67.6
	July 9	19.3	15.0-25.0	6.0	22.5	12.0-37.0	292.6
	July 30	16.6	11.6-21.6	0.7	19.1	13.5-21.4	5.8
	August 20	--	--	0	24.1	18.8-34.0	1.4
Cyprinidae							
Unidentifiable Cyprinidae[a]	June 18	--	--	0	9.4	9.4	0.8
	July 9	8.8	5.5-14.7	3.3	8.0	5.8-16.0	5.8
	July 30	7.0	5.5-15.0	18.0	7.1	5.5-10.1	271.6
	August 20	14.8	5.9-24.0	3.7	11.9	6.2-19.8	10.1
Centrarchidae							
Sunfishes (Lepomis spp.)	June 18	--	--	0	6.7	4.2-9.6	13.4
	July 9	16.2	16.2	0.3	16.1	15.9-16.4	2.0
	July 30	--	--	0	--	--	0
	August 20	--	--	0	--	--	0

[a] This grouping includes larval cyprinids (except common carp) that could not be further identified.

Table I-8. Number and percentage composition of fishes collected with three quantitative gears in submergent vegetation in Lawrence Lake (Pool 8, Upper Mississippi River).

Taxa	Electrofishing frame		Drop net		Pop net	
	Number caught	Percent of catch	Number caught	Percent of catch	Number caught	Percent of catch
Cyprinidae						
Common carp	0	0	2	<1	0	0
Emerald shiner	0	0	1	<1	43	11
Ictaluridae						
Tadpole madtom	0	0	0	0	1	<1
Centrarchidae						
Largemouth bass	1	6	3	<1	3	<1
Warmouth	0	0	5	1	11	3
Bluegill	16	94	212	55	261	65
Sunfishes (Lepomis spp.)	0	0	160	41	81	20
Black crappie	0	0	1	<1	0	0
Percidae						
Yellow perch	0	0	1	<1	0	0
Johnny darter	0	0	1	<1	0	0
Total (all taxa)	17		386		400	

Table I-9. Mean total length (mm range in parentheses) and mean total catch (± SD) of species collected during quantitative gear evaluation in submergent vegetation in Lawrence Lake (Pool 8, Upper Mississippi River).

Taxa	July			August			September		
	Electrofishing frame	Drop net	Pop net	Electrofishing frame	Drop net	Pop net	Electrofishing frame	Drop net	Pop net
				Total length of fish					
Cyprinidae									
Common carp	--	--	--	--	453	--	--	--	--
Emerald shiner	--	--	13	--	--	--	--	41	48 (39-57)
Ictaluridae									
Tadpole madtom	--	--	--	--	--	--	--	--	42
Centrarchidae									
Largemouth bass	--	54 (51-57)	--	--	--	80 (73-86)	73 (59-87)	65	71
Warmouth	--	--	--	--	37	28 (22-33)	--	51 (34-89)	--
Bluegill	61 (56-80)	68 (64-76)	53 (33-63)	--	36 (29-78)	29 (18-87)	35 (21-84)	32 (17-80)	32 (21-80)
Sunfishes (Lepomis spp.)	--	19 (15-27)	21 (15-26)	--	25 (18-29)	--	--	--	--
Black crappie	--	--	--	--		71	--	--	--
Percidae									
Yellow perch	--	65 (65)	--	--	--	--	--	--	--
Johnny darter	--	38 (38)	--	--	--	--	--	--	--
				Mean number of fish caught					
	<1 (1)	47 (3)	30 (13)	0	28 (23)	47 (32)	5 (1)	54 (18)	56 (20)

Table I-10. A comparison of enumerated catch and estimated catch (estimated from three and four seine hauls with the Zippin [1958] method) in replicated tests with the drop net in Lawrence Lake (Pool 8, Upper Mississippi River). Percent difference between enumerated and estimated catch is given in parentheses.

Month	Replicate	Enumerated catch (number of fish)	Estimated catch (number of fish)	
			Three hauls	Four hauls
July	1	52	65 (+25)	54 (+4)
	2	22	22 (0)	23 (+4)
	3	67	63 (-9)	69 (+3)
August	1	31	28 (-10)	33 (+6)
	2	50	51 (+2)	47 (-6)
	3	4[a]	--	--
September	1	64	66 (+3)	62 (-3)
	2	64	92 (+44)	69 (+8)
	3	33	31 (-6)	34 (+3)

[a] Sample size was too small to use the Zippin method.

Table I-11. Mean capture efficiency (± SD) of the electrofishing frame in replicated tests in vegetated and nonvegetated habitats in Lawrence Lake (Pool 8, Upper Mississippi River).

Habitat type	Month	Capture efficiency (%)
Vegetated	July	1 (0.6)
	September	11 (0.7)
		3 (1.5)
Nonvegetated	September	60 (1.8)
		90 (3.2)
		91 (0.9)

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Table I-12. Taxa caught by four sampling gears as a function of habitat type in Lawrence Lake, Pool 8, Upper Mississippi River (1 = present in catch, 0 = absent in catch).

Time and taxa collected	Gill net			Hoop net			Minnow trap		Fyke net	
	EM	SUB	OW	EM	SUB	OW	EM	SUB	EM	SUB
				Daytime sampling						
Lepisosteidae										
Longnose gar	0	0	1	0	0	0	0	0	0	0
Shortnose gar	0	0	0	0	0	0	0	0	0	1
Amiidae										
Bowfin	0	0	1	0	0	0	0	0	0	0
Clupeidae										
Gizzard shad	0	0	1	0	0	0	0	0	0	0
Esocidae										
Northern pike	0	0	1	0	0	0	0	0	0	0
Cyprinidae										
Common carp	0	1	1	0	0	0	0	0	0	0
Golden shiner	1	0	1	0	0	0	0	0	0	0
Emerald shiner	0	0	0	0	0	0	0	0	0	0
Catostomidae										
Spotted sucker	0	0	1	0	0	0	0	0	0	0
Ictaluridae										
Yellow bullhead	0	0	0	0	1	0	0	0	0	0
Percichthyidae										
White bass	0	0	1	0	0	0	0	0	0	0
Centrarchidae										
Warmouth	0	0	0	1	1	0	1	1	1	1
Pumpkinseed	0	1	0	1	0	0	1	0	1	0
Bluegill	1	0	1	1	1	1	1	0	1	1
White crappie	0	1	1	0	0	0	0	0	0	1
Black crappie	0	0	0	0	0	0	0	0	1	1
Total number of species caught	2	3	10	3	2	1	3	1	4	5

Table I-12. Continued.

Time and taxa collected	Gill net			Hoop net			Minnow trap		Fyke net	
	EM	SUB	OW	EM	SUB	OW	EM	SUB	EM	SUB
Nighttime sampling										
Lepisosteidae										
Longnose gar	0	0	1	0	0	0	0	0	0	0
Amiidae										
Bowfin	0	0	0	0	0	0	0	0	0	1
Clupeidae										
Gizzard shad	0	0	1	0	0	0	0	0	0	0
Cyprinidae										
Golden shiner	1	0	1	0	0	0	0	0	0	1
Common carp	0	1	1	0	0	0	0	0	0	1
Emerald shiner	0	0	0	1	0	0	0	0	0	0
Pugnose minnow	0	0	0	0	0	0	0	0	0	1
Catostomidae										
Spotted sucker	0	0	0	0	0	0	0	0	0	1
Ictaluridae										
Yellow bullhead	0	0	0	0	0	0	0	0	0	0
Tadpole madtom	0	0	0	0	0	0	1	0	0	0
Percichthyidae										
White bass	0	0	0	0	0	0	0	0	1	0
Centrarchidae										
Warmouth	0	0	0	1	1	0	1	1	0	1
Pumpkinseed	0	0	0	0	1	0	1	0	0	1
Bluegill	0	0	0	1	0	1	1	0	0	1
White crappie	0	0	1	0	0	0	0	0	0	1
Black crappie	0	0	0	1	0	0	0	0	0	1
Total number of species caught	1	1	5	4	3	1	4	1	1	10

EM = emergent vegetation, SUB = submergent vegetation, OW = open water

Table I-13. Total numbers of individuals and species (in parentheses) of fish caught with four sampling gears in Lawrence Lake (Pool 8, Upper Mississippi River).

Month of sampling	Gill net			Hoop net			Minnow trap			Fyke net		
	EM	SUB	OW	EM	SUB	OW	EM	SUB	OW	EM	SUB	OW
Daytime sampling												
July	0	1 (1)	4 (2)	--	--	--	--	--	--	--	--	--
August	3 (2)	1 (1)	17 (8)	20 (3)	2 (1)	1 (1)	11 (3)	1 (1)	--	--	--	--
September	0	3 (1)	1 (1)	9 (2)	11 (3)	2 (1)	29 (2)	1 (1)	--	41 (5)	54 (5)	--
Nighttime sampling												
July	0	0	10 (2)	--	--	--	--	--	--	--	--	--
August	1 (1)	0	33 (5)	5 (2)	3 (2)	1 (1)	6 (1)	0	--	--	--	--
September	0	1 (1)	6 (1)	29 (4)	4 (2)	0	18 (4)	4 (1)	--	84 (6)	15 (6)	--

EM = emergent vegetation, SUB = submergent vegetation, OW = open water

Table I-14. Number, mean length (mm), and size range of fish collected during daytime and nighttime net sets in Lawrence Lake (Pool 8, Upper Mississippi River).

	Gill net				Hoop net				Minnow trap				Fyke net			
			Total length				Total length				Total length				Total length	
Species caught	Frequency	% of catch	Mean	Range	Frequency	% of catch	Mean	Range	Frequency	% of catch	Mean	Range	Frequency	% of catch	Mean	Range
								Daytime sampling								
Longnose gar	1	3	535		0	--	--	--	0	--	--	--	0	--	--	--
Shortnose gar	0	--	--	--	0	--	--	--	0	--	--	--	1	1	575	
Bowfin	1	3	299		0	--	--	--	0	--	--	--	0	--	--	--
Gizzard shad	2	7	66	65-68	0	--	--	--	0	--	--	--	0	--	--	--
Common carp	4	14	444	408-480	0	--	--	--	0	--	--	--	0	--	--	--
Golden shiner	13	45	139	87-165	0	--	--	--	0	--	--	--	0	--	--	--
Spotted sucker	1	3	77		0	--	--	--	0	--	--	--	0	--	--	--
Yellow bullhead	0	--	--	--	1	2	321		0	--	--	--	0	--	--	--
White bass	1	3	116		0	--	--	--	0	--	--	--	0	--	--	--
Warmouth	0	--	--	--	29	65	39	17-152	28	67	36	28-43	22	23	40	30-85
Pumpkinseed	1	3	90		1	2	83		1	2	36		1	1	96	
Bluegill	2	7	84	84-85	14	31	66	26-181	13	31	37	29-46	56	59	41	26-182
White crappie	3	10	77	58-112	0	--	--	--	0	--	--	--	11	12	64	58-72
Black crappie	0	--	--	--	0	--	--	--	0	--	--	--	4	4	163	121-223
Total catch	29				45				42				95			
								Nighttime sampling								
Longnose gar	1	2	320		0	--	--	--	0	--	--	--	0	--	--	--
Bowfin	0	--	--	--	0	--	--	--	0	--	--	--	1	1	467	
Gizzard shad	32	63	108	60-127	0	--	--	--	0	--	--	--	0	--	--	--
Common carp	5	10	455	425-502	0	--	--	--	0	--	--	--	5	5	555	431-775
Golden shiner	11	27	148	137-155	0	--	--	--	0	--	--	--	1	1	156	
Pugnose minnow	0	--	--	--	0	--	--	--	0	--	--	--	10	10	41	35-44
Emerald shiner	0	--	--	--	1	2	48		0	--	--	--	0	--	--	--
Spotted sucker	0	--	--	--	0	--	--	--	0	--	--	--	1	1	300	
Tadpole madtom	0	--	--	--	0	--	--	--	1	4	56		0	--	--	--
Warmouth	0	--	--	--	19	45	42	26-82	20	71	37	28-46	30	30	38	31-44
Pumpkinseed	0	--	--	--	0	--	--	--	2	7	57	35-79	1	1	38	
Bluegill	0	--	--	--	20	48	42	23-81	5	18	38	31-44	43	43	35	24-61
White crappie	2	4	64	64-65	0	--	--	--	0	--	--	--	5	5	65	63-66
Black crappie	0	--	--	--	2	5	122	114-130	0	--	--	--	3	3	62	58-67
Total catch	51				42				28				100			

Table I-15. Number and total length (mm) of fish caught during 12-h sets at the open water station during monthly gear evaluation studies in Lawrence Lake (Pool 8, Upper Mississippi River) July-September.

	Gill net			
	Catch		Total length (mm)	
Species caught	Frequency	Percent	Mean	Range
	Daytime sampling			
Longnose gar	1	5	535	
Bowfin	1	5	299	
Gizzard shad	2	9	66	65-68
Northern pike	1	5	500	
Common carp	1	5	455	
Golden shiner	11	50	142	87-165
Spotted sucker	1	5	77	
White bass	1	5	116	
Bluegill	1	5	85	
White crappie	2	9	60	58-61
Total catch	22			
	Nighttime sampling			
Longnose gar	1	2	320	
Gizzard shad	32	65	107	60-127
Common carp	4	8	459	425-502
Golden shiner	10	20	147	137-155
White crappie	2	4	64	64-65
Total catch	49			

Table I-16. Number and total length (mm) of fish caught during 24-h sets with three sampling gears in Lawrence Lake (Pool 8, Upper Mississippi River) in September.

	Hoop net				Minnow trap[a]				Fyke net			
	Catch		Total length		Catch		Total length		Catch		Total length	
Taxa	Frequency	%	Mean	Range	Frequency	%	Mean	Range	Frequency	%	Mean	Range
Lepisosteidae												
Shortnose gar	0	--	--	--	0	--	--	--	1	1	584	
Amiidae												
Bowfin	0	--	--	--	0	--	--	--	2	3	559	558-560
Esocidae												
Northern pike	0	--	--	--	0	--	--	--	1	1	770	
Cyprinidae												
Common carp	0	--	--	--	0	--	--	--	5	6	468	444-505
Golden shiner	0	--	--	--	1	33	109		2	3	111	109-113
Pugnose minnow	0	--	--	--	0	--	--	--	20	27	43	33-50
Catostomidae												
Spotted sucker	0	--	--	--	0	--	--	--	1	1	415	
Centrarchidae												
Warmouth	4	31	67	43-100	0	--	--	--	6	8	46	23-82
Pumpkinseed	1	8	52		0	--	--	--	1	1	40	
Bluegill	8	62	43	35-66	2	67	36	33-39	31	40	45	26-159
Black crappie	0	--	--	--	0	--	--	--	8	10	219	117-265
Total catch												
Number of fish	13				3				78			
Number of species	3				2				11			

[a] Catch from three replicates; nine replicates taken with hoop nets and fyke nets

Table I-17. Water quality parameters measured during light trap sampling in Lawrence Lake (Pool 8, Upper Mississippi River), 1990.

Date	Site	Station	Temperature (°C)	Dissolved oxygen (mg/L)	pH	Conductivity (µmho/cm)	Turbidity (NTU)
May 30-31	1	1 EM	23.6	8.5	8.0	311	18.0
		1 SN	22.5	9.0	8.7	279	10.0
		1 SO	22.0	7.6	8.6	268	10.0
	2	2 EM	23.3	9.8	8.1	341	12.0
		2 SN	23.1	9.5	8.1	344	10.0
		2 SO	22.3	8.8	8.2	328	6.0
June 18-19	1	1 EM	25.6	10.3	8.7	356	13.0
		1 SN	25.6	10.2	8.8	337	11.0
		1 SO	25.6	10.9	8.9	325	12.0
	2	2 EM	24.6	8.1	7.8	338	11.0
		2 SN	24.4	10.8	8.3	330	8.0
		2 SO	24.7	11.2	8.5	302	5.0
		OW	24.6	8.1	8.8	351	15.0
July 9-10	1	1 EM	23.6	4.8	7.0	294	--
		1 SN	23.5	4.1	7.2	320	--
		1 SO	24.4	6.6	7.1	339	--
	2	2 EM	23.9	4.6	7.1	386	--
		2 SN	24.0	6.8	7.4	360	--
		2 SO	24.6	7.3	7.5	336	--
		OW	25.1	11.1	8.2	335	10.0
July 30-31	1	1 EM	24.1	3.6	7.2	372	11.0
		1 SN	24.5	3.4	7.2	386	31.0
		1 SO	24.5	8.4	8.0	372	9.0
	2	2 EM	24.4	6.9	7.5	296	3.1
		2 SN	24.5	7.6	7.8	294	64.0
		2 SO	24.4	8.2	8.0	298	23.0
		OW	25.1	10.9	8.4	378	11.0
August 20-21	1	1 EM	20.0	2.9	6.9	352	14.0
		1 SN	20.9	2.3	6.9	356	31.0
		1 SO	21.1	5.1	7.2	338	17.0
	2	2 EM	20.8	2.4	7.0	287	15.0
		2 SN	21.6	6.4	7.5	286	16.0
		2 SO	22.7	10.6	8.1	288	3.5
		OW	21.6	6.7	7.2	324	23.0

EM = emergent, SN = submergent nearshore, SO = submergent offshore, OW = open water

Table I-18. Mean vegetation biomass and vegetation richness of aquatic vegetation at light trap sampling stations in Lawrence Lake (Pool 9, Upper Mississippi River).

Date	Site	Station	Mean dry-weight biomass (g/m^2)	Vegetation richness (number of taxa)
May 30	1	1 EM	130.2	8
		1 SN	304.8	8
		1 SO	284.3	6
	2	2 EM	101.1	8
		2 SN	171.1	8
		2 SO	211.4	4
June 18	1	1 EM	160.5	8
		1 SN	78.7	8
		1 SO	155.0	4
	2	2 EM	181.9	8
		2 SN	152.0	7
		2 SO	309.7	6
July 9	1	1 EM	441.8	7
		1 SN	240.5	7
		1 SO	82.5	6
	2	2 EM	203.4	7
		2 SN	155.0	6
		2 SO	186.9	5
July 30	1	1 EM	319.5	8
		1 SN	160.7	7
		1 SO	94.5	6
	2	2 EM	341.2	8
		2 SN	217.7	10
		2 SO	241.8	4
August 20	1	1 EM	427.1	9
		1 SN	98.1	6
		1 SO	84.0	7
	2	2 EM	263.4	8
		2 SN	155.9	6
		2 SO	148.5	5

EM = emergent, SN = submergent nearshore, SO = submergent offshore

Table I-19. Percent composition of catch in light traps by date and site in Lawrence Lake (Pool 8, Upper Mississippi River).

	May 30-31			June 18-19			July 9-10			July 30-31			August 20-21		
	Site			Site			Site			Site			Site		
Taxa	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Clupeidae															
Gizzard shad	0	0	0	0	<1	0	0	0	35	0	0	3	0	0	0
Cyprinidae															
Common carp	0	0	0	3	<1	60	0	1	0	0	0	0	0	0	0
Golden shiner	0	42	0	3	1	0	0	0	0	0	0	0	0	0	0
Emerald shiner	0	0	0	0	0	20	0	4	2	0	0	0	24	0	15
Minnows	0	0	0	<1	<1	0	0	0	0	0	0	0	0	0	0
Unidentifiable Cyprinidae[a]	100	0	0	3	<1	0	0	0	19	29	0	92	14	0	21
Atherinidae															
Brook silverside	0	0	0	0	<1	7	6	0	42	57	20	5	44	27	63
Percichthyidae															
Temperate basses (Morone spp.)	0	0	0	0	0	7	0	0	0	0	0	0	0	0	
Centrarchidae															
Largemouth bass	0	0	0	<1	0	0	0	0	0	0	0	0	0	0	0
Warmouth	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0
Bluegill	0	0	0	0	<1	0	18	0	0	14	53	0	18	55	0
Sunfishes (Lepomis spp.)	0	0	0	91	98	0	77	95	2	0	27	0	0	9	0
Crappies (Pomoxis spp.)	0	58	0	0	0	0	0	0	0	0	0	0	0	0	0
Percidae															
Darters (Lepomis spp.)	0	0	0	<1	0	0	0	0	0	0	0	0	0	0	0
Sciaenidae															
Freshwater drum	0	0	0	<1	0	7	0	0	0	0	0	0	0	0	0

[a] This grouping includes larval cyprinids (except common carp) that could not be further identified.

Site codes: 1 = lower vegetated site, 2 = upper vegetated site, 3 = open-water site

Table I-20. Percent composition of catch in light traps by station in Lawrence Lake (Pool 8, Upper Mississippi River).

	Site 1			Site 2			Site 3
Taxa	EM	SN	SO	EM	SN	SO	OW
Clupeidae							
Gizzard shad	0	0	0	0.1	0	0	11.2
Cyprinidae							
Common carp	0.6	1.5	31.3	0.4	0.6	7.7	5.0
Golden shiner	1.6	6.0	2.3	3.0	0.6	0	0
Emerald shiner	0	0	9.0	0.2	0	0	0
Unidentifiable Cyprinidae[a]	4.1	0	6.7	0.2	0..0	0	42.2
Atherinidae							
Brook silverside	0	0	20.9	0.1	0.2	11.5	33.1
Percichthyidae							
Temperate basses (Morone spp.)	0	0	0	0	0	0	0.6
Centrarchidae							
Largemouth bass	0.1	0.2	0	0	0	0	0
Warmouth	0	0	0	0.1	0	0	0
Bluegill	1.2	0	0.7	0.1	0.1	7.7	0
Sunfishes (Lepomis spp.)	91.9	92.3	29.1	94.9	98.5	71.2	0.6
Crappies (Pomoxis spp.)	0	0	0	0.7	0	0	0
Percidae							
Darters (Percina spp.)	0.1	0	0	0	0	0	0
Sciaenidae							
Freshwater drum	0.1	0	0	0	0	0	0.6

[a] This grouping includes larval cyprinids (except common carp) that could not be further identified.

EM = emergent vegetation, SN = submergent nearshore, SO = submergent offshore, OW = open water

Table I-21. Mean total catch (number of fishes, all taxa combined) and standard deviation (in parentheses) in light traps in Lawrence Lake (Pool 8, Upper Mississippi River).

Site	Station type	May 30-31	June 18-19	July 9-10	July 30-31	August 20-21
1	Emergent	0.6 (1.1)	408.6 (86.6)	10.3 (2.5)	0	3.0 (3.0)
	Submergent nearshore	0	194.0 (157.2)	0	0	0
	Submergent offshore	0	27.7 (7.0)	1.0 (1.7)	2.3 (2.1)	13.7 (9.3)
2	Emergent	4.0 (4.3)	386.0 (178.5)	22.3 (7.6)	2.0 (1.0)	2.0 (1.7)
	Submergent nearshore	0	680.3 (154.6)	7.3 (4.5)	1.5 (2.1)	0.3 0.6)
	Submergent offshore	0	11.3 (8.7)	2.7 (3.2)	2.0 (1.0)	1.3 (1.5)
3	Open water	0	5.0 (1.0)	17.0 (7.0)	19.7 (6.8)	17.6 (2.9)

Table I-22. Mean catch (number of fish) and standard deviation (in parentheses) in light traps in Lawrence Lake (Pool 8, Upper Mississippi River).

	May 30-31			June 18-19			July 9-10			July 30-31			August 20-21		
Taxa	EM	SN	SO	EM	SN	SO	EM	SN	SO	EM	SN	SO	EM	SN	SO
								Site 1							
Cyprinidae															
Common carp	0	0	0	2.3 (2.5)	3.0 (3.6)	14.0 (2.6)	0	0	0	0	0	0	0	0	0
Golden shiner	0	0	0	7.0 (12.1)	11.7 (8.1)	1.0 (1.7)	0	0	0	0	0	0	0	0	0
Emerald shiner	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.0 (6.1)
Minnows	0	0	0	1.3 (2.3)	0	0	0	0	0	0	0	0	0	0	0
Unidentifiable Cyprinidae[a]	0.7 (1.2)	0	0	16.7 (10.1)	0	0	0	0	0	0	0	0.7 (1.2)	0	0	2.3 (1.5)
Atherinidae															
Brook silverside	0	0	0	0	0	0	0	0	0.7 (1.2)	0	0	1.3 (1.5)	0	0	7.3 (5.5)
Centrarchidae															
Largemouth bass	0	0	0	0.3 (0.6)	0.3 (0.6)	0	0	0	0	0	0	0	0	0	0
Bluegill	0	0	0	0	0	0	2.0 (2.0)	0	0	0	0	0.3 (0.6)	3.0 (3.0)	0	0
Sunfishes (*Lepomis* spp.)	0	0	0	380.0 (82.3)	179.0 (149.8)	12.7 (10.0)	8.3 (2.1)	0	0.3 (0.6)	0	0	0	0	0	0
Percidae	0	0	0	0.3 (0.6)	0	0	0	0	0	0	0	0	0	0	0
Darters (*Lepomis* spp.)	0	0	0	0.3 (0.6)	0	0	0	0	0	0	0	0	0	0	0
Sciaenidae															
Freshwater drum	0	0	0	0.7 (1.2)	0	0	0	0	0	0	0	0	0	0	0

Table I-22. Continued.

	May 30-31			June 18-19			July 9-10			July 30-31			August 20-21		
Taxa	EM	SN	SO	EM	SN	SO	EM	SN	SO	EM	SN	SO	EM	SN	SO
								Site 2							
Clupeidae															
Gizzard shad	0	0	0	0.3 (0.6)	0	0	0	0	0	0	0	0	0	0	0
Cyprinidae															
Common carp	0	0	0	1.3 (1.2)	4.0 (5.3)	1.0 (0)	0	0	0.3 (0.6)	0	0	0	0	0	0
Golden shiner	1.7 (2.1)	0	0	10.3 (8.5)	4.0 (3.6)	0	0	0	0	0	0	0	0	0	0
Emerald shiner	0	0	0	0	0	0	1.0 (1.7)	0	0.3 (0.6)	0	0	0	0	0	0
Minnows	0	0	0	1.0 (1.0)	0	0	0	0	0	0	0	0	0	0	0
Unidentifiable Cyprinidae[a]	0	0	0	1.0 (1.7)	0	0	0	0	0	0	0	0	0	0	0
Atherinidae															
Brook silverside	0	0	0	0.3 (0.6)	1.3 (1.5)	0	0	0	0	0	0	1.0 (1.0)	0	0	1.0 (1.0)
Centrarchidae															
Warmouth	0	0	0	0	0	0	0	0	0	0	0	0	0.3 (0.6)	0	0
Bluegill	0	0	0	0	0	0.3 (0.6)	0	0	0	1.7 (1.2)	0.5 (0.7)	0.7 (1.2)	1.3 (0.6)	0.3 (0.6)	0.3 (0.6)
Sunfishes (*Lepomis* spp.)	0	0	0	371.7 (164.4)	671.0 (157.5)	10.0 (9.2)	21.3 (6.4)	7.3 (4.5)	2.0 (3.5)	0.3 (0.6)	1.0 (1.4)	0.3 (0.6)	0.3 (0.6)	0	0
Crappies (*Pomoxis* spp.)	2.3 (2.3)	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table I-22. Continued.

	May 30-31	June 18-19	July 9-10	July 30-31	August 20-21
Taxa	OW	OW	OW	OW	OW
			Site 3		
Clupeidae					
Gizzard shad	0	0	0	0.7 (0.6)	0
Cyprinidae					
Common carp	0	3.0 (1.0)	0	0	0
Emerald shiner	0	1.0 (1.0)	0.3 (0.6)	0	2.7 (1.2)
Unidentifiable Cyprinidae[a]	0	0	3.3 (2.1)	18.0 (7.2)	3.7 (2.5)
Atherinidae					
Brook silverside	0	0.3 (0.6)	7.3 (1.2)	1.0 (1.0)	11.0 (0)
Percichthyidae					
Temperate basses (Morone spp.)	0	0.3 (0.6)	0	0	0
Centrarchidae					
Sunfishes (Lepomis spp.)	0	0	0.3 (0.6)	0	0
Sciaenidae					
Freshwater drum	0	0.3 (0.6)	0	0	0

[a] This grouping includes larval cyprinids (except common carp) that could not be further identified.

EM = emergent, SN = submergent nearshore, SO = submergent offshore, OW = open water

Table I-23. Results of analysis of variance and Student-Newman-Keuls multiple range tests to examine variation in mean catch among sites and station type. Sites or station types with the same superscript are not statistically different from each other at $\alpha = 0.05$. Mean catch and ± SD are given in parentheses.

Habitat	Group included in catch	$\underline{P}^x$	Student-Newman-Keuls multiple range			
Site	Total catch	0.55	1 (45.1 ± 11.74)	2 (76.5 ± 198.1)	3 (11.9 ± 8.9)	
	Lepomis spp.	0.05	$1^{a,b}$ (39.6 ± 109.9)	2^{a} (74.0 ± 194.7)	3^{b} (0.1 ± 0.3)	
	Unidentifiable Cyprinidae*	0.01	1^{a} (1.4 ± 3.8)	2^{a} (0.1 ± 0.4)	3^{b} (5.5 ± 5.5)	
Station type	Total catch	0.2	EM (86.8 ± 169.8)	SN (91.3 ± 220.1)	SO (6.2 ± 9.5)	OW (11.9 ± 8.9)
	Lepomis spp.	0.01	EM^{a} (80.9 ± 161.1)	SN^{a} (88.8 ± 216.5)	$SO^{a,b}$ (2.5 ± 5.8)	OW^{b} (0.1 ± 0.3)
	Unidentifiable Cyprinidae*	0.01	EM^{a} (1.9 ± 5.8)	SN^{a} (0)	SO^{a} (0.3 ± 0.9)	OW^{b} (5.0 ± 7.5)

*This grouping includes larval cyprinids (except common carp) that could not be further identified.

EM = emergent, SN = submergent nearshore, SO = submergent offshore, OW = open water

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Table I-24. Results of analysis of variance and Student-Newman-Keuls multiple range test for differences among sites for sampling periods. Probability value *P* is included. Stations with the same superscript are not statistically different from each other at $\alpha = 0.05$.

Sampling period	Catch characteristic	*P*[x]	Student-Newman-Keuls multiple range						
5/30-5/31	Total catch	0.01**	1-EM^{b}	1-SN^{b}	1-SO^{b}	2-EM^{a}	2-SN^{b}	2-SO^{b}	3-OW^{b}
	Lepomis spp.	--	--	--	--	--	--	--	-- -
	Unidentifiable Cyprinidae***	0.46							
6/18/-6/19	Total catch	0.00**	1-EM^{a,b}	1-SN^{b}	1-SO^{c}	2-EM^{a,b}	2-SN^{a}	2-SO^{d}	3-OW^{d}
	Lepomis spp.	0.00**	1-EM^{a,b}	1-SN^{b}	1-SO^{c}	2-EM^{a,b}	2-SN^{a}	2-SO^{c}	3-OW^{d}
	Unidentifiable Cyprinidae	0.00**	1-EM^{a}	1-SN^{b}	1-SO^{b}	2-EM^{b}	2-SN^{b}	2-SO^{b}	3-OW^{b}
7/09-7/10	Total catch	0.00**	1-EM^{a}	1-SN^{b}	1-SO^{b}	2-EM^{a}	2-SN^{a}	2-SO^{b}	3-OW^{a}
	Lepomis spp.	0.00**	1-EM^{a}	1-SN^{b}	1-SO^{b}	2-EM^{a}	2-SN^{a}	2-SO^{b}	3-OW^{b}
	Unidentifiable Cyprinidae	0.00**	1-EM^{b}	1-SN^{b}	1-SO^{b}	2-EM^{b}	2-SN^{b}	2-SO^{b}	3-OW^{a}
7/30-7/31	Total catch	0.00**	1-EM^{b}	1-SN^{b}	1-SO^{b}	2-EM^{b}	2-SN^{b}	2-SO^{b}	3-OW^{a}
	Lepomis spp.	0.49							
	Unidentifiable Cyprinidae	0.00**	1-EM^{b}	1-SN^{b}	1-SO^{b}	2-EM^{b}	2-SN^{b}	2-SO^{b}	3-OW^{a}
8/20-8/21	Total catch	0.00**	1-EM^{a}	1-SN^{a}	1-SO^{b}	2-EM^{a}	2-SN^{a}	2-SO^{a}	3-OW^{b}
	Lepomis spp.	0.46							
	Unidentifiable Cyprinidae	0.00**	1-EM^{a}	1-SN^{a}	1-SO^{b}	2-EM^{a}	2-SN^{a}	2-SO^{a}	3-OW^{b}

[x] Levels of statistical differences

*$P \leq 0.05$

**$P \leq 0.01$

***This grouping includes larval cyprinids (except common carp) that could not be further identified.

EM = emergent, SN = submergent nearshore, SO = submergent offshore, OW = open water

Table I-25. Mean developmental stage of fish caught with light traps in Lawrence Lake (Pool 8, Upper Mississippi River). Developmental codes 1 = protolarvae with yolk, 2 = protolarvae, 3 = mesolarvae, 4 = metalarvae, 5 = juvenile, 6 = adult.

	May 30-31			June 18-19			July 9-10			July 30-31			August 20-21		
Taxa	EM	SN	SO	EM	SN	SO	EM	SN	SO	EM	SN	SO	EM	SN	SO
Site 1															
Cyprinidae															
Common carp	--	--	--	2.1	2.1	2.4	--	--	--	--	--	--	--	--	--
Golden shiner	--	--	--	3.0	3.0	3.3	--	--	--	--	--	--	--	--	--
Emerald shiner	--	--	--	--	--	--	--	--	--	--	--	--	--	--	6.0
Minnows	--	--	--	5.0	--	--	--	--	--	--	--	--	--	--	--
Unidentifiable Cyprinidae*	2.0	--	--	2.4	--	--	--	--	--	--	--	3.0	--	--	2.8
Atherinidae															
Brook silverside	--	--	--	--	--	--	--	--	6.0	--	--	4.8	--	--	5.4
Centrarchidae															
Largemouth bass	--	--	--	2.0	3.0	--	--	--	--	--	--	--	--	--	--
Bluegill	--	--	--	--	--	--	5.0	--	--	--	--	5.0	5.0	--	--
Sunfishes (*Lepomis* spp.)	--	--	--	2.0	3.0	2.4	4.8	--	5.0	--	--	--	--	--	--
Percidae															
Darters (*Lepomis* spp.)	--	--	--	4.0	--	--	--	--	--	--	--	--	--	--	--
Sciaenidae															
Freshwater drum	--	--	--	3.0	--	--	--	--	--	--	--	--	--	--	--

Table I-25. Continued.

	May 30-31			June 18-19			July 9-10			July 30-31			August 20-21		
Taxa	EM	SN	SO	EM	SN	SO	EM	SN	SO	EM	SN	SO	EM	SN	SO
								Site 2							
Clupeidae															
Gizzard shad	--	--	--	2.0	--	--	--	--	--	--	--	--	--	--	--
Cyprinidae															
Common carp	--	--	--	2.5	2.0	3.0	--	--	2.0	--	--	--	--	--	--
Golden shiner	2.0	--	--	2.5	3.1	--	--	--	--	--	--	--	--	--	--
Emerald shiner	--	--	--	--	--	--	5.3	--	5.0	--	--	--	--	--	--
Minnows	--	--	--	5.0	--	--	--	--	--	--	--	--	--	--	--
Unidentifiable Cyprinidae[a]	--	--	--	4.0	--	--	--	--	--	--	--	--	--	--	--
Atherinidae															
Brook silverside	--	--	--	3.0	3.0	--	--	--	--	--	--	6.0	--	--	6.0
Centrarchidae															
Warmouth	--	--	--	--	--	--	--	--	--	--	--	--	5.0	--	--
Bluegill	--	--	--	--	--	5.0	--	--	--	5.0	5.0	5.0	5.0	5.0	5.0
Sunfishes (Lepomis spp.)	--	--	--	2.6	2.5	2.4	4.6	4.8	4.7	4.0	5.0	5.0	5.0	--	--
Crappies (Pomoxis spp.)	2.3	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Table I-25. Continued.

	May 30-31	June 18-19	July 9-10	July 30-31	August 20-21
Taxa	OW	OW	OW	OW	OW
			Site 3		
Clupeidae					
Gizzard shad	--	--	3.7	3.5	--
Cyprinidae					
Common carp	--	3.0	--	--	--
Emerald shiner	--	6.0	6.0	--	6.0
Unidentifiable Cyprinidae[a]	--	--	3.0	2.5	4.2
Atherinidae					
Brook silverside	--	1.0	5.0	5.0	5.1
Percichthyidae					
Temperate basses (*Morone* spp.)	--	4.0	--	--	--
Centrarchidae					
Sunfishes (*Lepomis* spp.)	--	--	5.0	--	--
Sciaenidae					
Freshwater drum	--	1.0	--	--	--

[a] This grouping includes larval cyprinids (except common carp) that could not be further identified.

EM = emergent, SN = submergent nearshore, SO = submergent offshore, OW = open water

Table I-26. Mean catch (in number of fish per 100 m^3 of water filtered) caught with 0.5-m plankton net at the open water station, Lawrence Lake (Pool 8, Upper Mississippi River).

Taxa	May 30		June 18		July 9		July 30		August 20	
	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night
Clupeidae										
Gizzard shad	3.6	0	0	67.6	0.5	292.6	1.0	5.8	0	1.4
Cyprinidae										
Unidentifiable Cyprinidae[a]	0	0	0.8	0.8	1.7	5.8	771.8	271.6	12.3	10.1
Common carp	0	0	0	11.0	0	0	0	0	0	0
Emerald shiner	0	0	0	0	0	0	0	0	0	0.4
Atherinidae										
Brook silverside	0	0	0	0	0	0	0	0	0	1.0
Percichthyidae										
Temperate basses (Morone spp.)	0	0	0	3.1	0	0	0	0	0	0
Centrarchidae										
Bluegill	0	0	0	0	0	0	0	0	0	0.9
Sunfishes (Lepomis spp.)	0	0	0	13.4	1.0	2.0	0	0	0	0
Percidae										
Darters (Lepomis spp.)	0	0	0	1.0	0	0	0	0	0	0
Sciaenidae										
Freshwater drum	0	0	0	3.1	0	0	0	0.7	0	0

[a] This grouping includes larval cyprinids (except common carp) that could not be further identified.

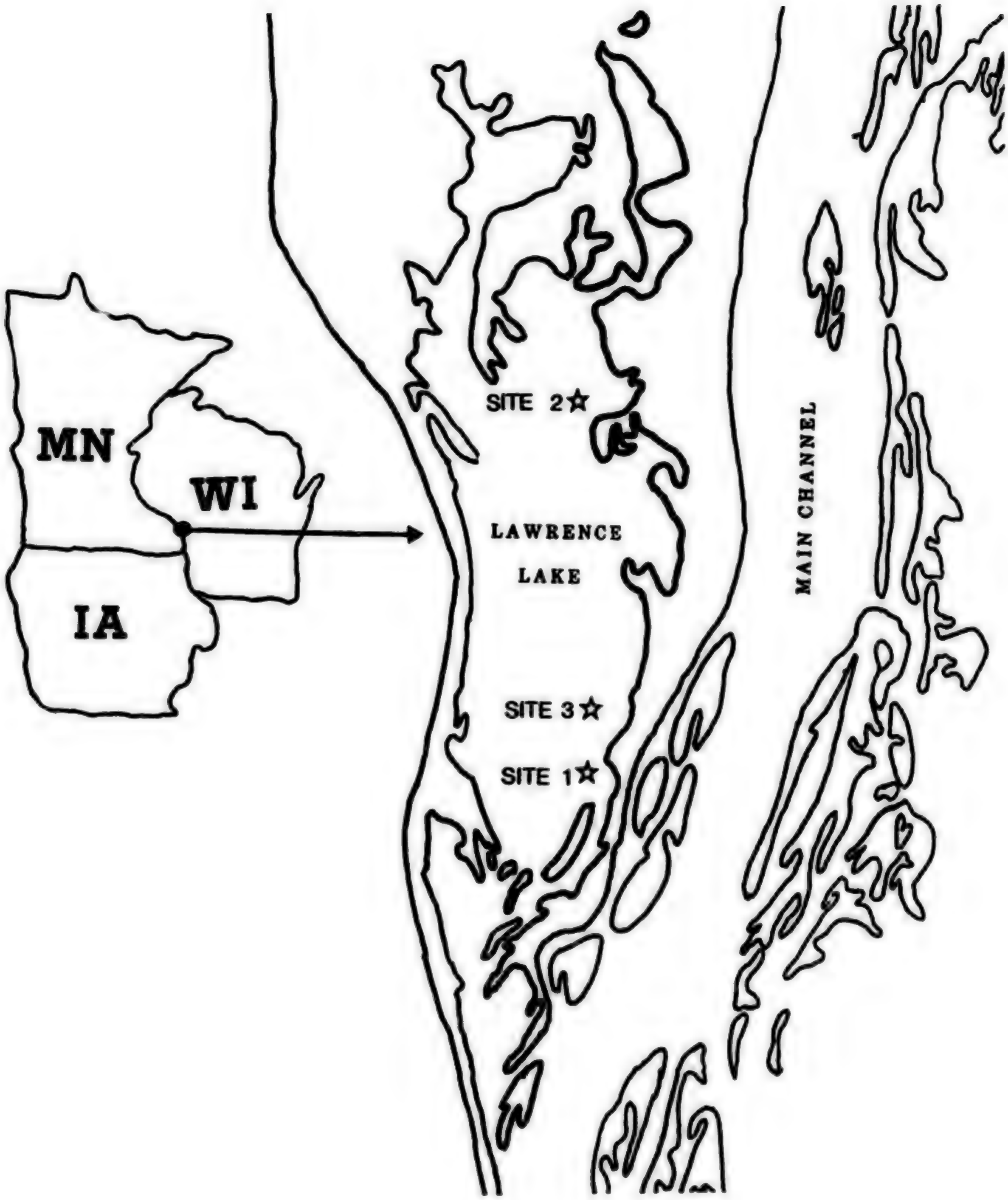

Figure I-1. Map of study sites in Lawrence Lake (Pool 8, Upper Mississippi River).

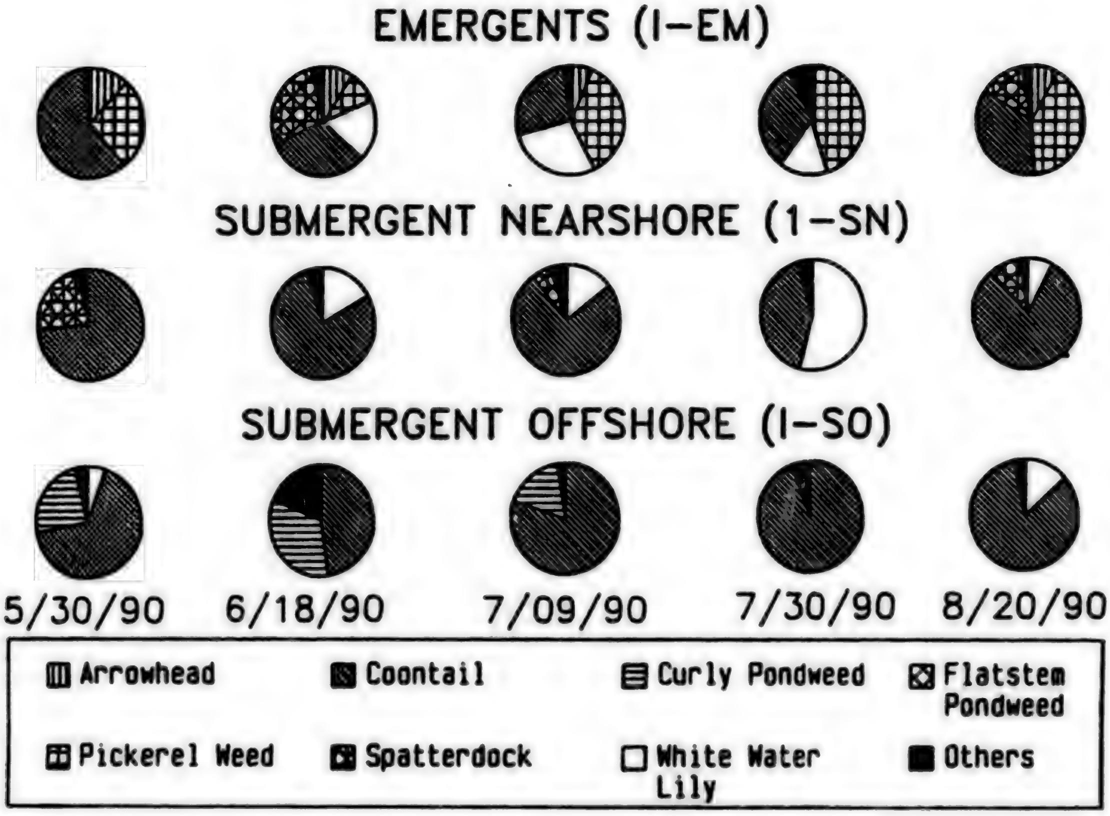

Figure I-2. Composition of aquatic macrophyte samples by the proportion of dry-weight biomass collected during light trap sampling at site 1, Pool 8, Upper Mississippi River.

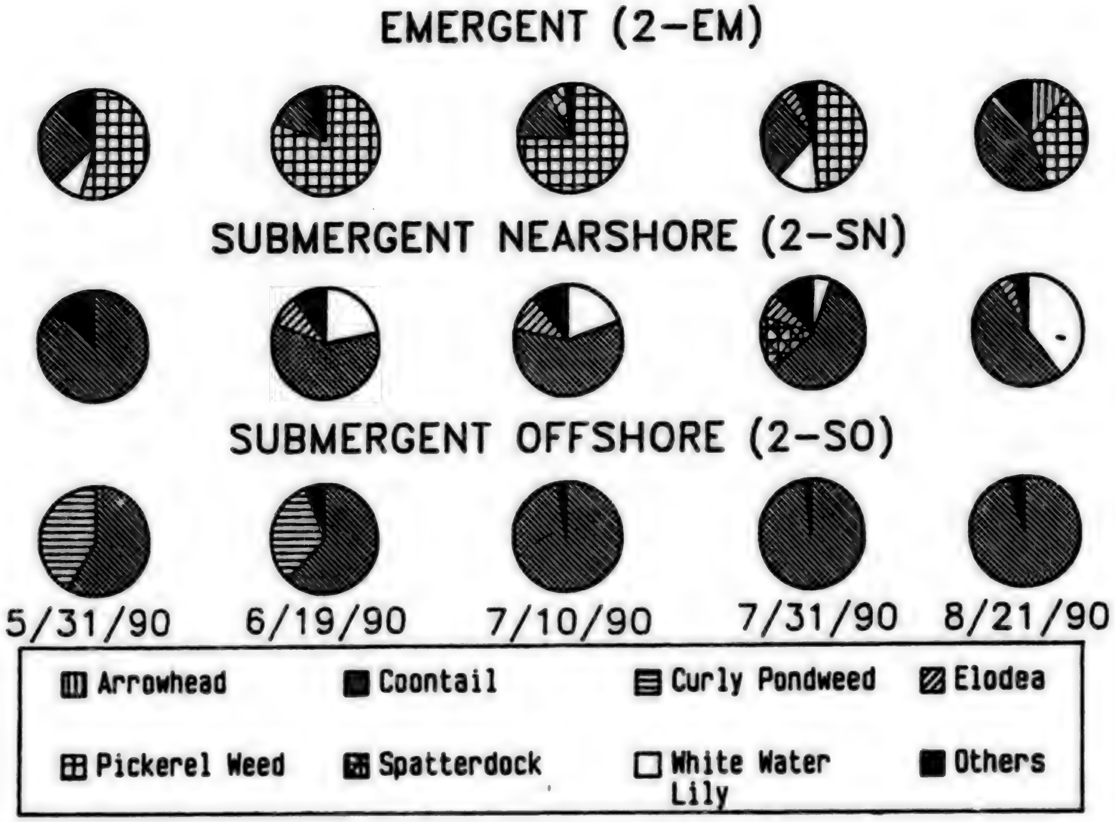

Figure I-3. Composition of aquatic macrophyte samples by the proportion of dry-weight biomass collected during light trap sampling at site 2, Pool 8, Upper Mississippi River.

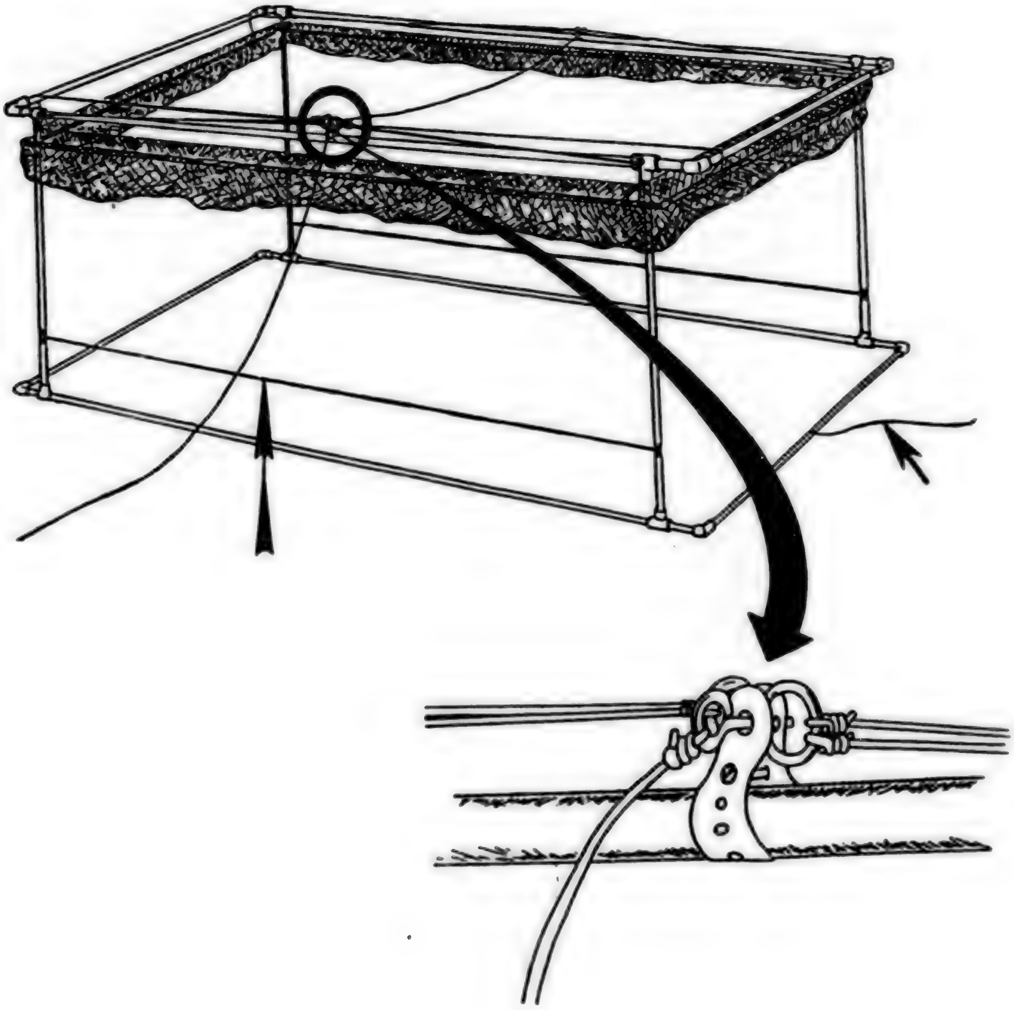

Figure I-4. Sampling device used as an electrofishing frame and drop net (A) and (B) release mechanism to lower netting.

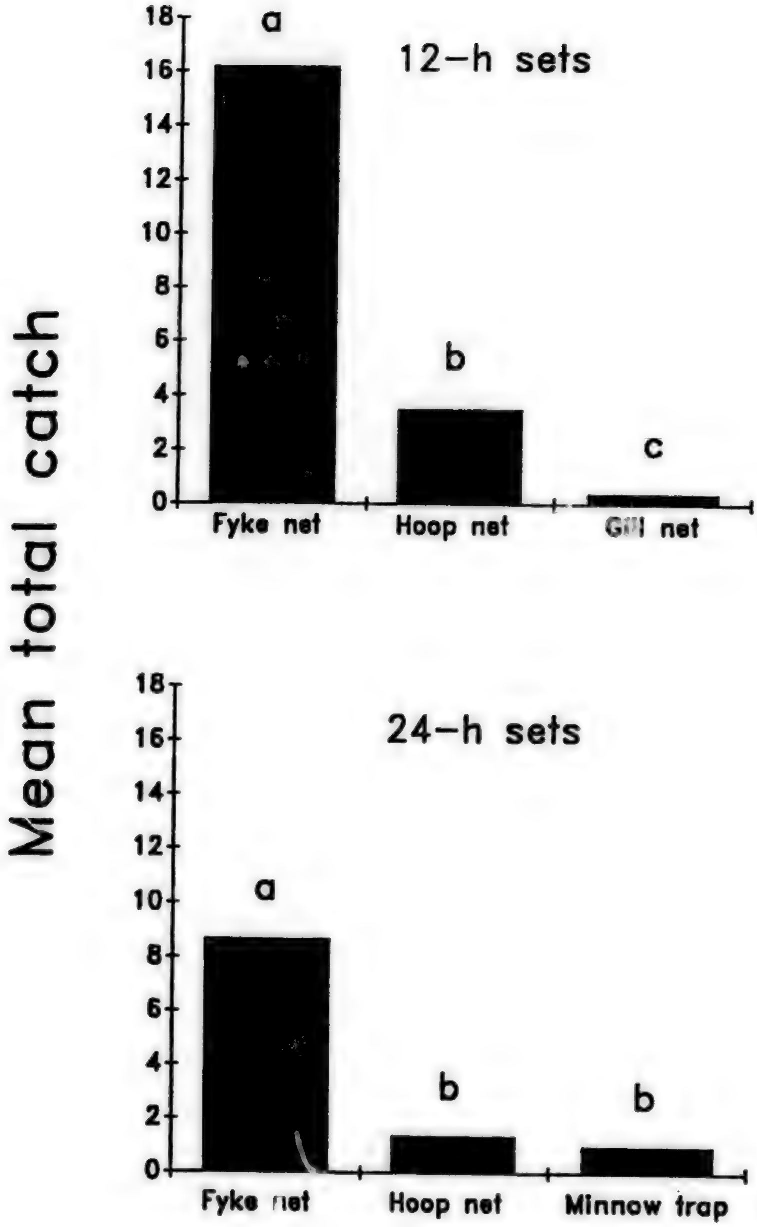

Figure I-5. Mean total catch of fish in replicated sets with three gear types in Lawrence Lake (Pool 8, Upper Mississippi River). Bars on a graph with the same letter are not statistically different from each other in total catch at $\alpha = 0.05$.

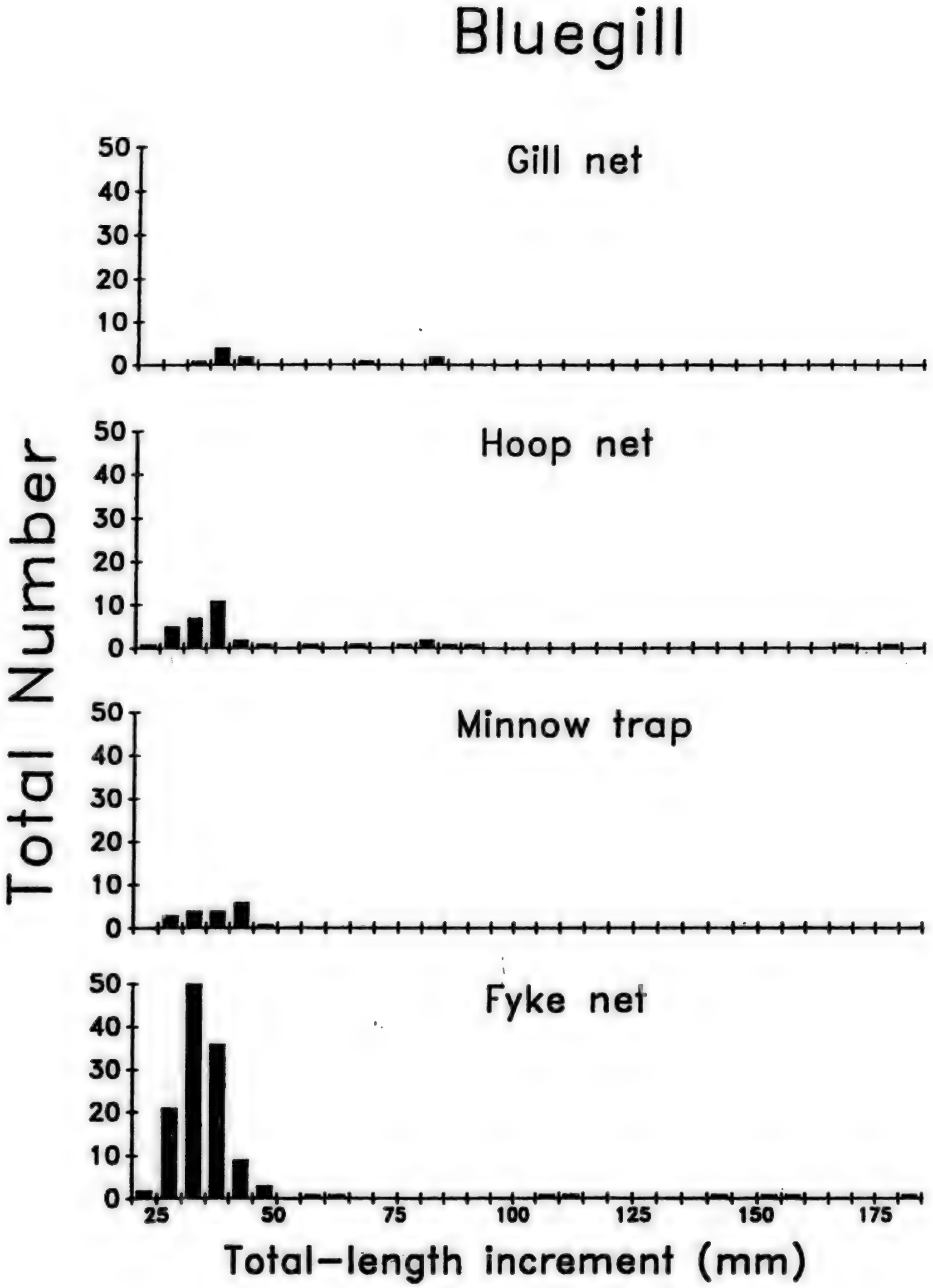

Figure I-6. Length frequency (in 5-mm increments) of bluegills caught with four sampling gears in both 12- and 24-h sets in Lawrence Lake (Pool 8, Upper Mississippi River).

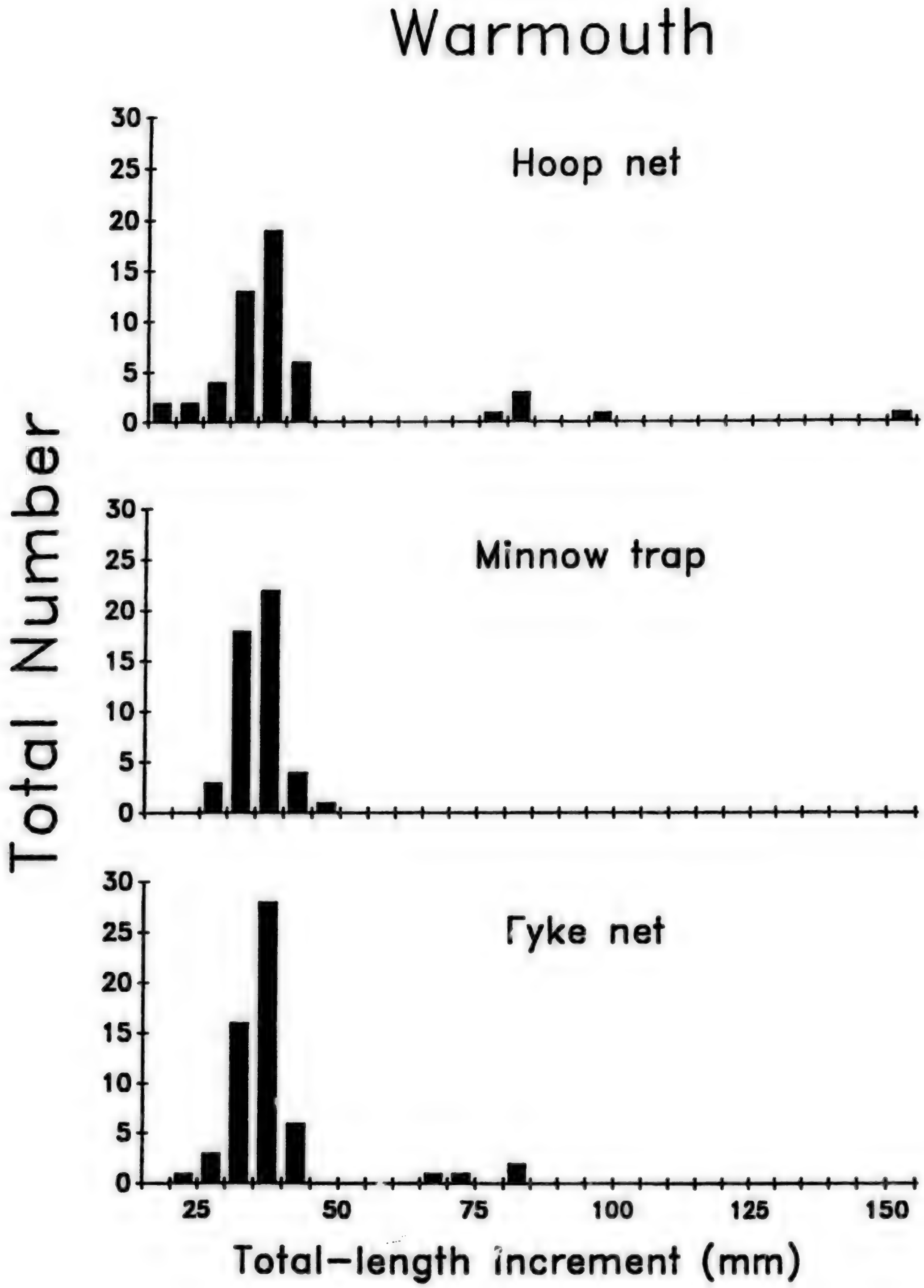

Figure I-7. Length frequency (in 5-mm increments) of warmouth caught with three sampling gears in both 12- and 24-h sets in Lawrence Lake (Pool 8, Upper Mississippi River).

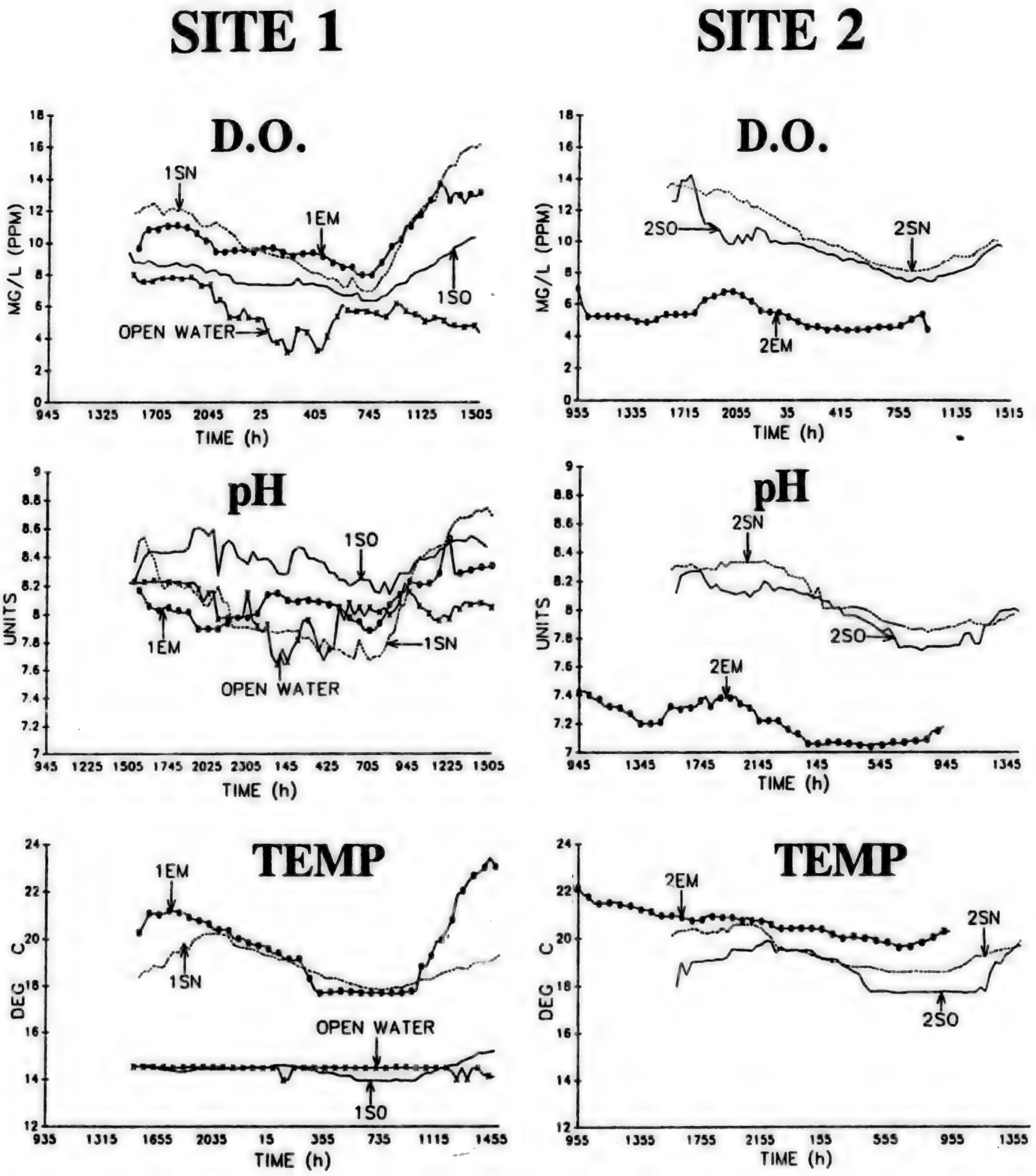

Figure I-8. Diel patterns of water quality parameters measured by 24-h monitoring during the week after the first light trap sampling period (May 30-31, 1990) in Lawrence Lake (Pool 8, Upper Mississippi River). 1 EM refers to Site 1, emergent vegetation station; 1 SN refers to Site 1, submergent nearshore station; 1 SO refers to Site 1, submergent offshore station; 2 EM refers to Site 2, emergent vegetation station; 2 SN refers to Site 2, submergent nearshore station; and 2 SO refers to Site 2, submergent offshore station.

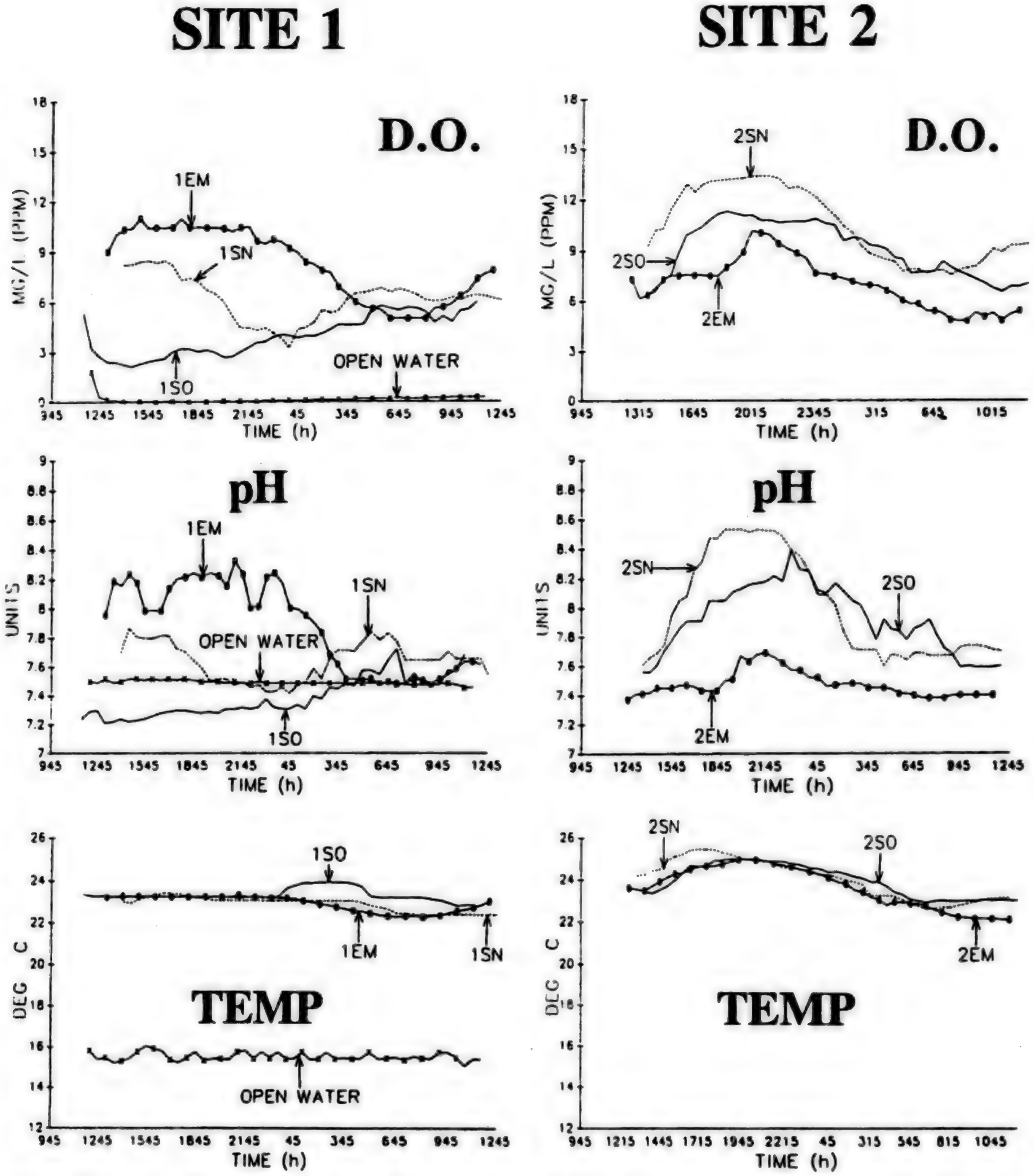

Figure I-9. Diel patterns of water quality parameters measured by 24-h monitoring during the second light trap sampling period (June 18-19, 1990) in Lawrence Lake (Pool 8, Upper Mississippi River). 1 EM refers to Site 1, emergent vegetation station; 1 SN refers to Site 1, submergent nearshore station; 1 SO refers to Site 1, submergent offshore station; 2 EM refers to Site 2, emergent vegetation station; 2 SN refers to Site 2, submergent nearshore station; and 2 SO refers to Site 2, submergent offshore station.

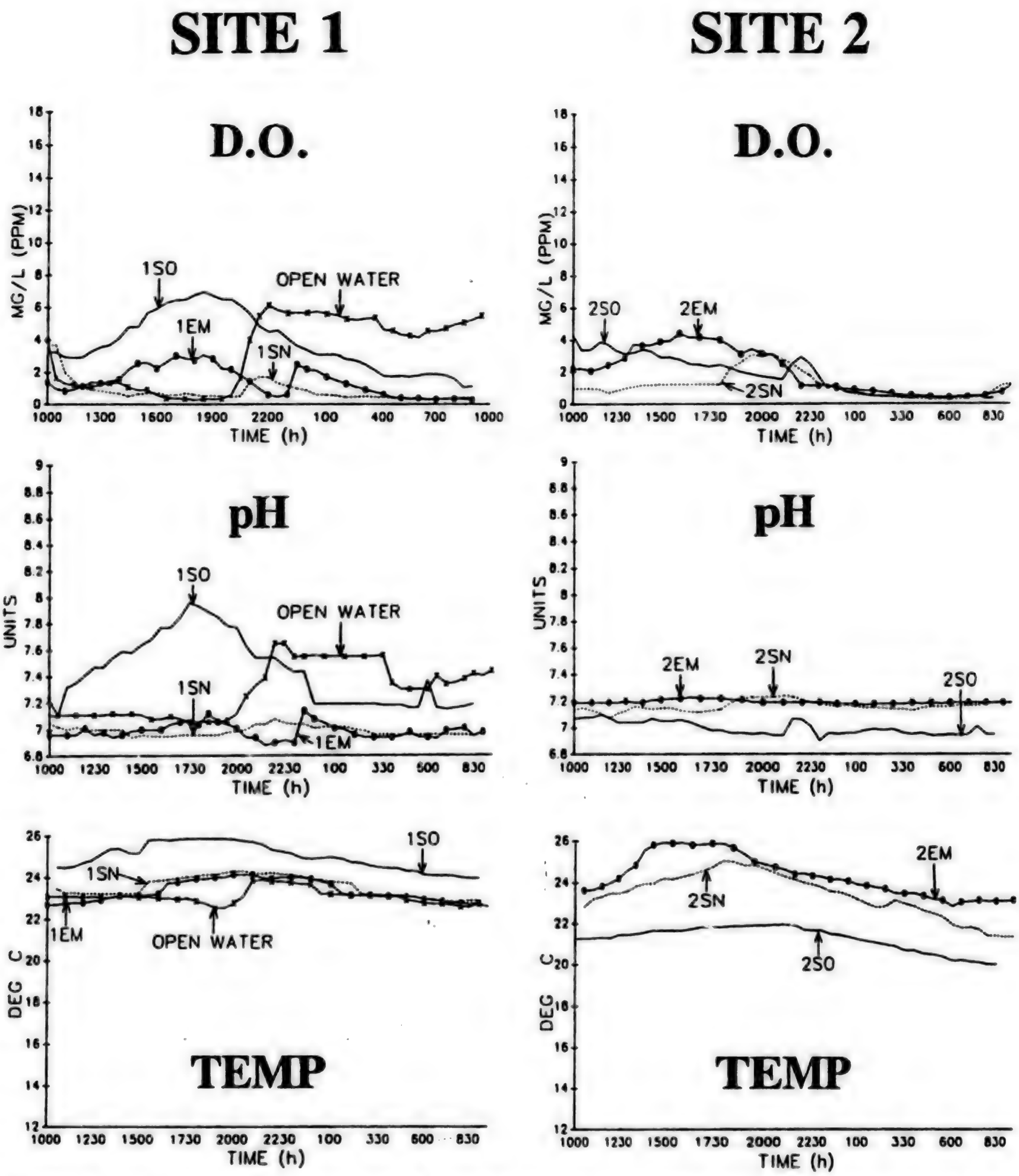

Figure I-10. Diel patterns of water quality parameters measured by 24-h monitoring during the third light trap sampling period (July 9-10, 1990) in Lawrence Lake (Pool 8, Upper Mississippi River). 1 EM refers to Site 1, emergent vegetation station; 1 SN refers to Site 1, submergent nearshore station; 1 SO refers to Site 1, submergent offshore station; 2 EM refers to Site 2, emergent vegetation station; 2 SN refers to Site 2, submergent nearshore station; and 2 SO refers to Site 2, submergent offshore station.

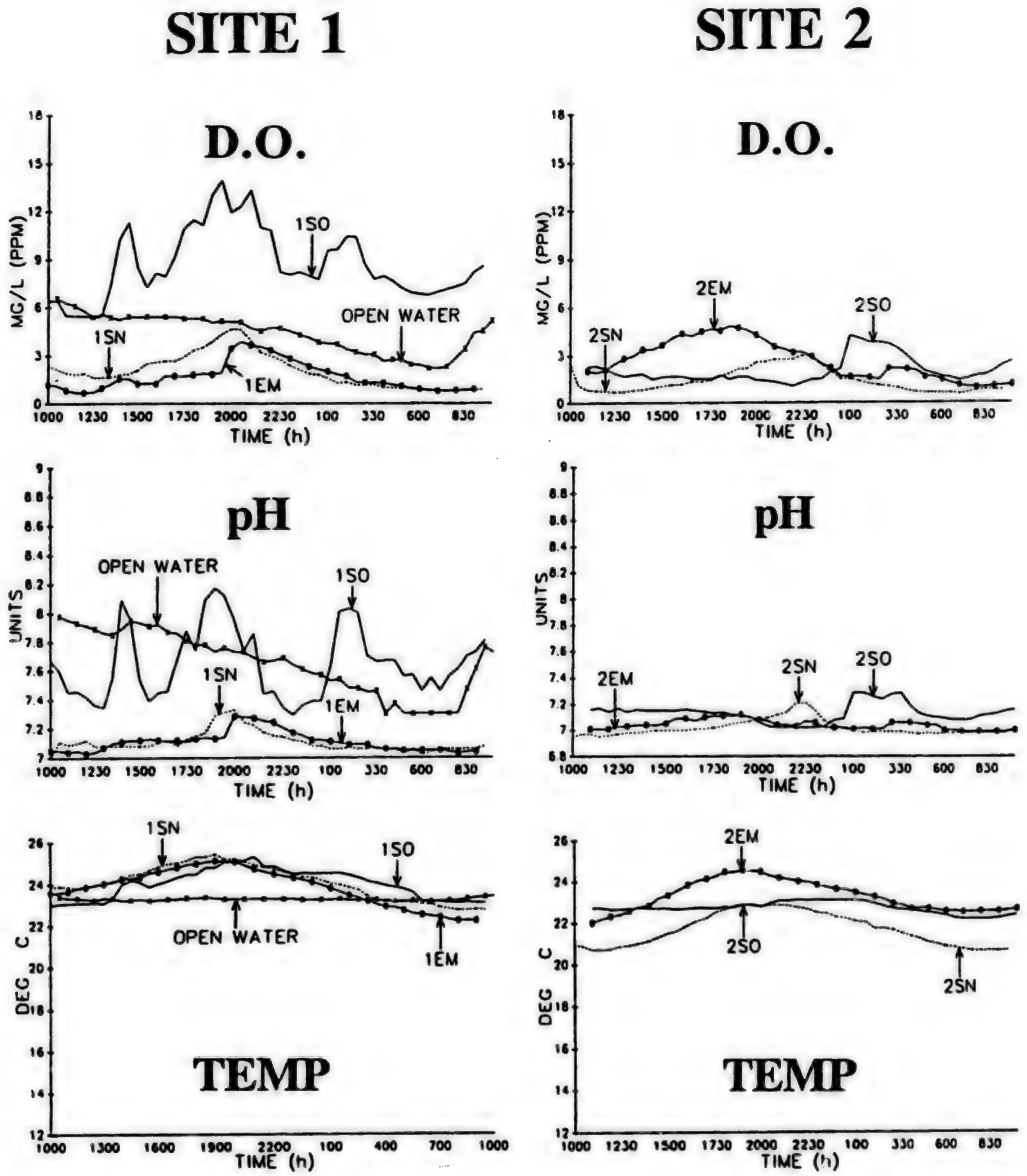

Figure I-11. Diel patterns of water quality parameters measured by 24-h monitoring during the fourth light trap sampling period (July 30-31, 1990) in Lawrence Lake (Pool 8, Upper Mississippi River). 1 EM refers to Site 1, emergent vegetation station; 1 SN refers to Site 1, submergent nearshore station; 1 SO refers to Site 1, submergent offshore station; 2 EM refers to Site 2, emergent vegetation station; 2 SN refers to Site 2, submergent nearshore station; and 2 SO refers to Site 2, submergent offshore station.

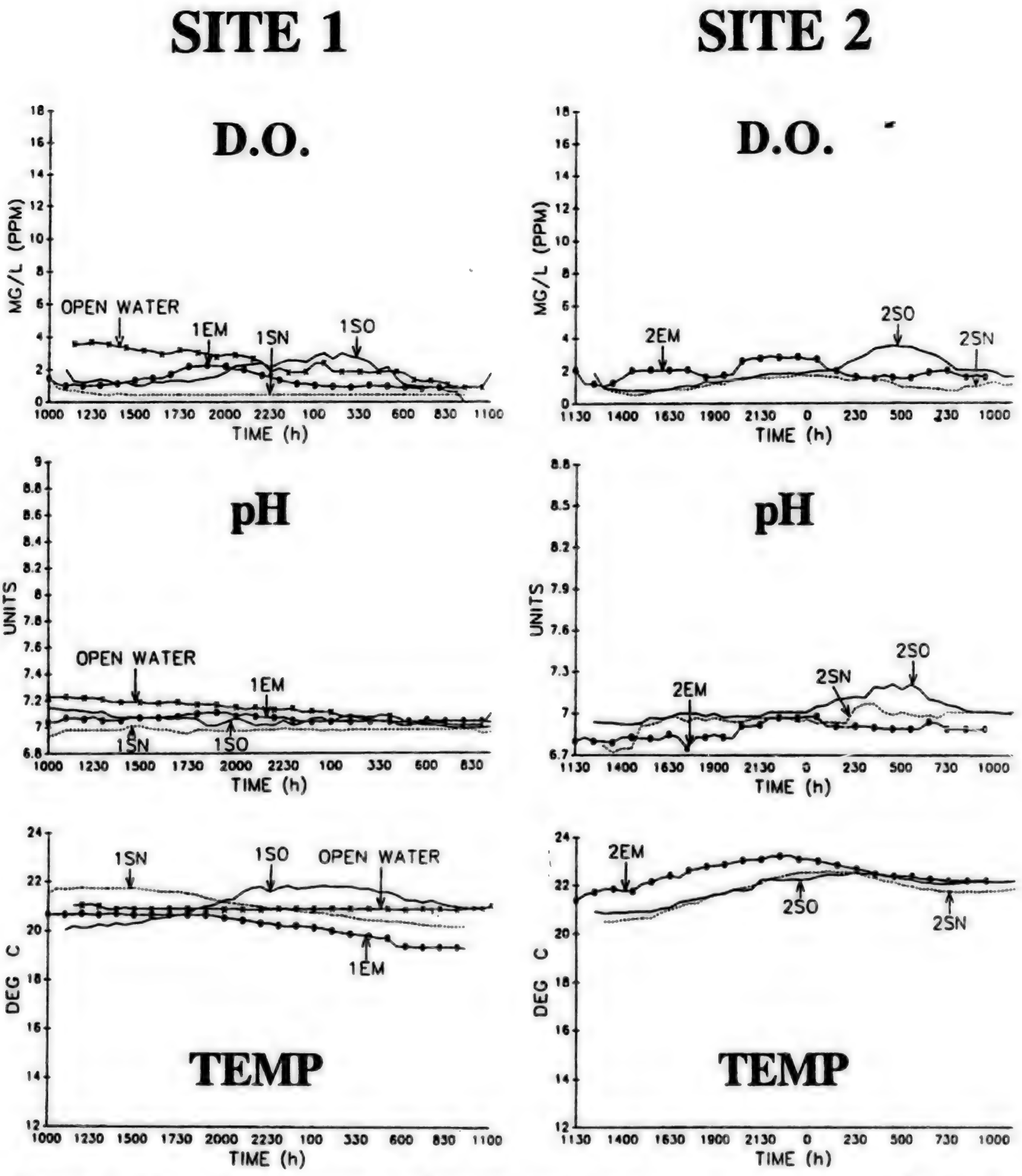

Figure I-12. Diel patterns of water quality parameters measured by 24-h monitoring during the fifth light trap sampling period (August 20-21, 1990) in Lawrence Lake (Pool 8, Upper Mississippi River). 1 EM refers to Site 1, emergent vegetation station; 1 SN refers to Site 1, submergent nearshore station; 1 SO refers to Site 1, submergent offshore station; 2 EM refers to Site 2, emergent vegetation station; 2 SN refers to Site 2, submergent nearshore station; and 2 SO refers to Site 2, submergent offshore station.

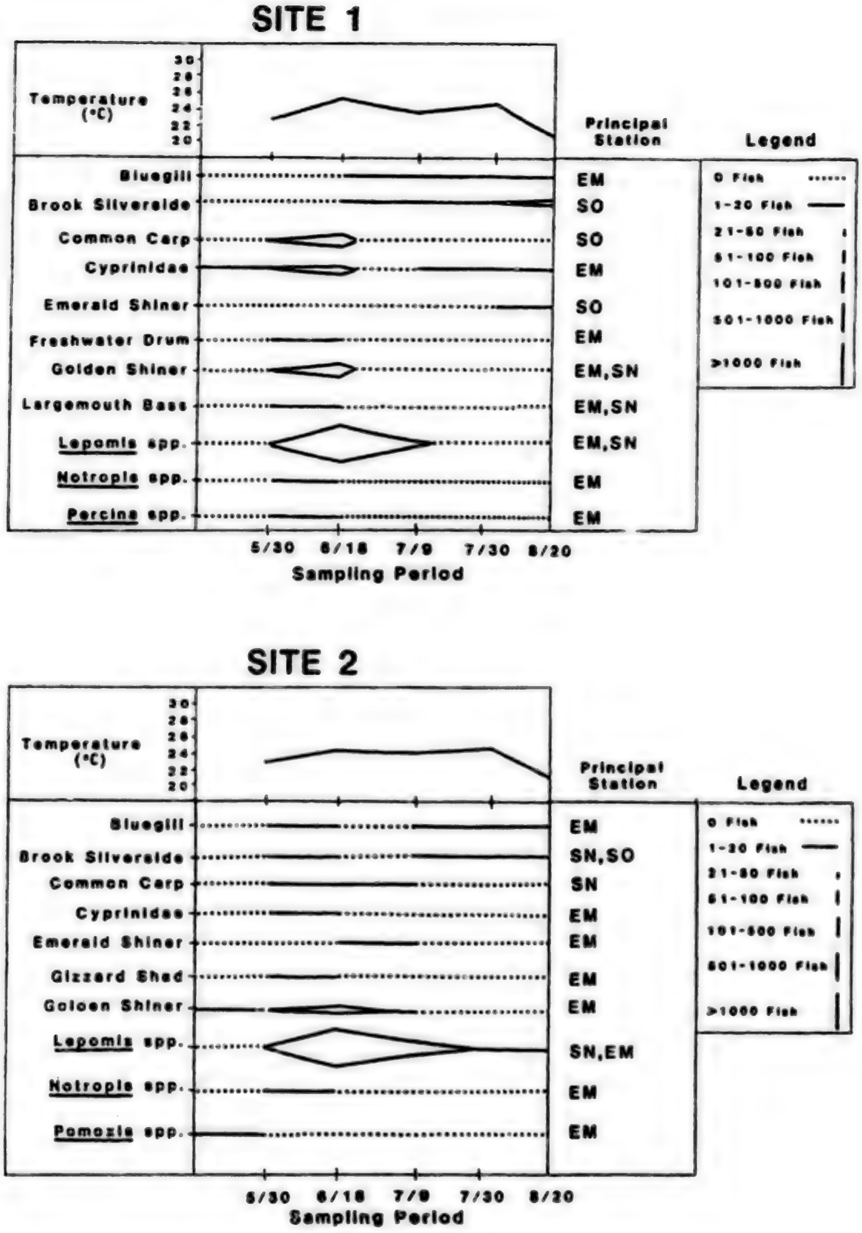

Figure I-13. Seasonal pattern in the catch of fishes in light traps at the two vegetated sites (1 and 2) sampled in Lawrence Lake (Pool 8, Upper Mississippi River).

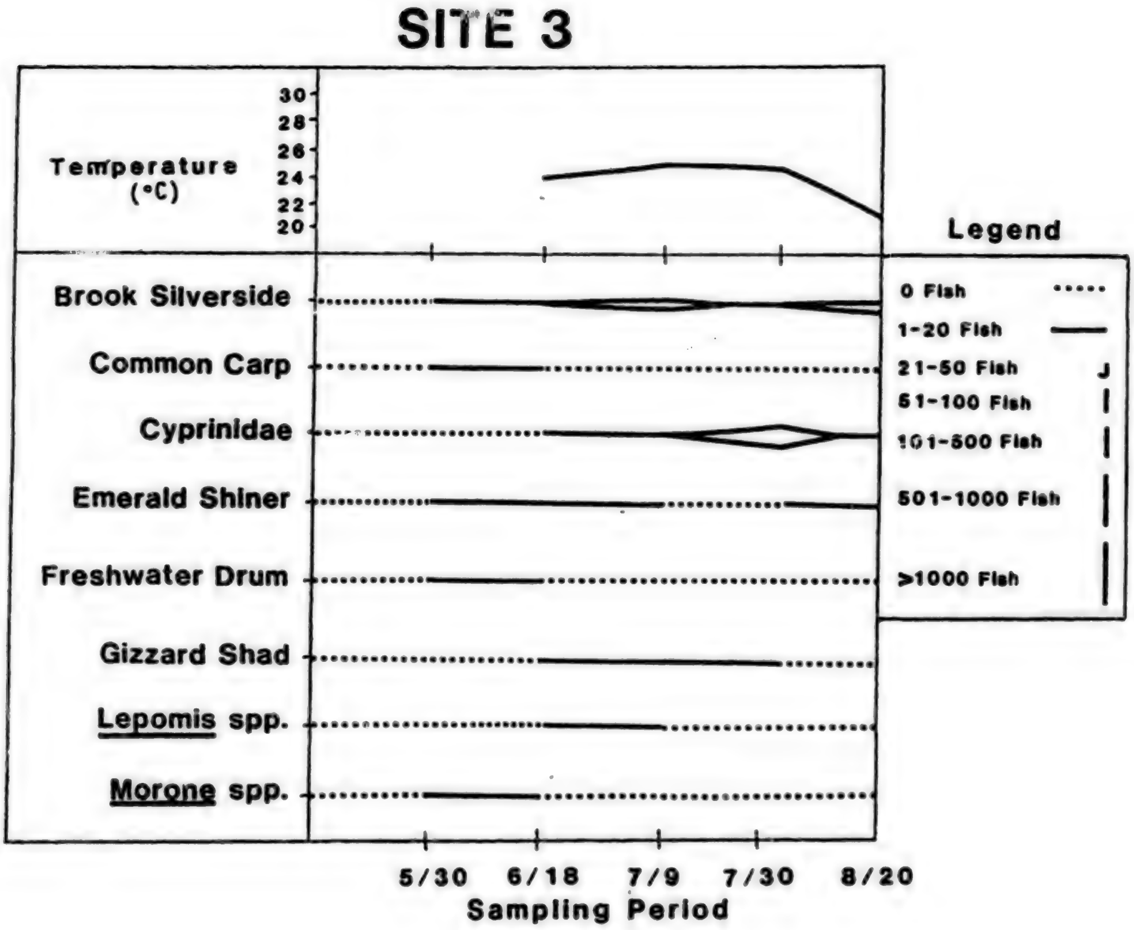

Figure I-14. Seasonal pattern in the catch of fishes collected in light traps at the open water site (3) sampled in Lawrence Lake (Pool 8, Upper Mississippi River).

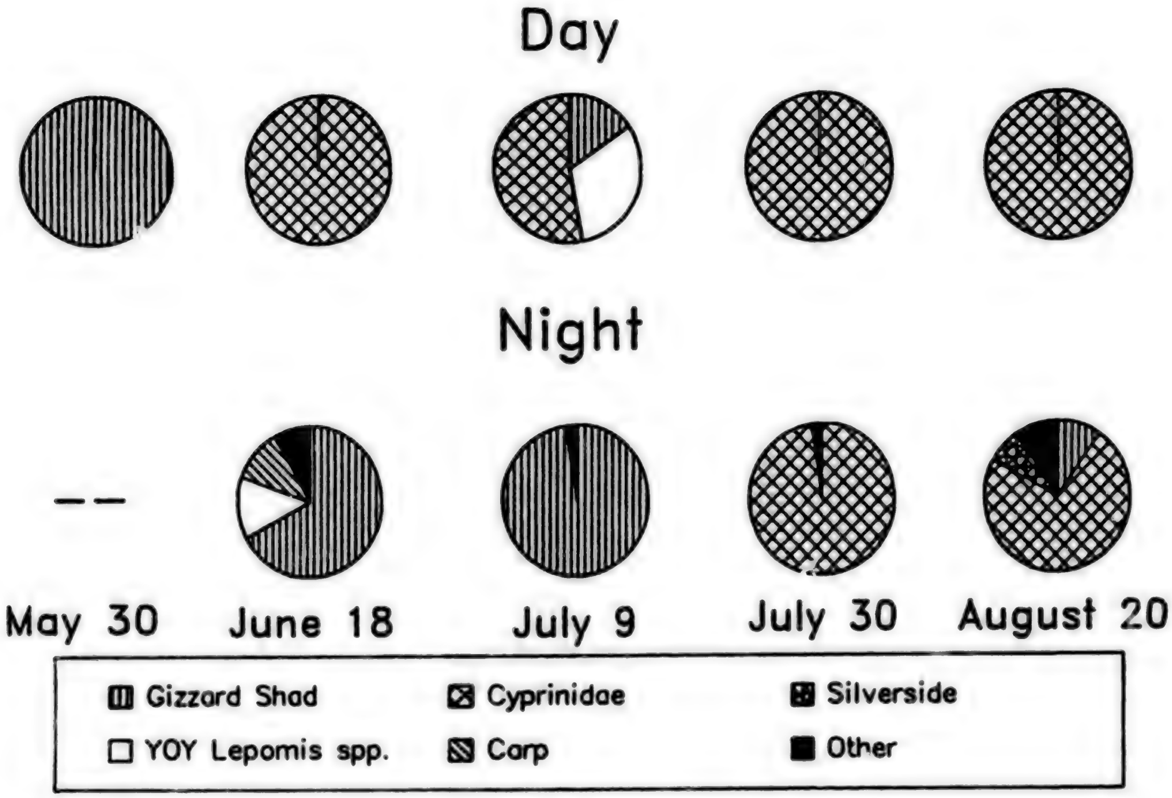

Figure I-15. Diel patterns of utilization of the open water site of fishes collected by 0.5-m net sampling in Lawrence Lake (Pool 8, Upper Mississippi River) in 1990.

Part II: Use of Aerial Videography to Monitor Vegetation Types in Backwater Habitats

II. Use of Aerial Videography to Monitor Vegetation Types in Backwater Habitats

Summary

We evaluated the utility of aerial videography and aerial photography (digitized transparencies) for classifying and mapping aquatic vegetation in a backwater lake of the Upper Mississippi River. Of the two methods, the transparency-based feature maps offered better resolution than the video-based feature maps. We believe the video- and transparency-based feature maps would have been more accurate if our vegetation sampling efforts in the lake were intensified. The proposed protocol for transect sampling of vegetation should achieve better representation of plants and enhance discrimination between vegetation classes. Given consistent discrimination among plant types, feature map interpretation is directly related to habitat complexity, a factor that should be considered in study design.

Introduction

Classification and mapping of wetland areas on the Upper Mississippi River are necessary for effective management strategies in the region (Werth and Lillesand 1979). Classification should be sufficiently definitive to provide classes that are mutually exclusive and depict transition zones among classes (Avery and Berlin 1985). Airborne remote sensing, including aerial photography and satellite imagery, is a proven technique for monitoring and classifying aquatic habitats (Ellis and Woitowich 1989). Unlike more traditional methods of collecting field data, remote sensing offers permanent images that may be stored for later analysis with optical, mechanical, or electronic devices not available in the field. Additionally, sensors used in remote sensing can collect data from the range of electromagnetic spectra not visible to the human eye (Ellis and Woitowich 1989).

Aerial videography is a relatively inexpensive, easy-to-use alternative to other remote sensing techniques such as satellite imagery. The equipment is available commercially, offers immediate availability of the imagery, and allows interaction between those obtaining the imagery and those surveying the vegetation. Furthermore, the electronic format of video data allows direct entry for computer-assisted analysis and interpretation (Meisner 1986). Aerial videography, as compared to photography, suffers from limited resolution of larger areas and seems best suited to small-scale applications or applications with narrow image width (Meisner 1986; Ellis and Woitowich 1989).

Applications of aerial videography as a remote sensing tool have steadily increased since the early 1980s. Aerial videography has been used for agricultural applications such as detection of diseased potato plants (Manzer and Cooper 1982), detection of freeze-damaged citrus leaves (Escobar et al. 1983), assessment of weed infestation among agricultural crops (Richardson et al. 1985), evaluation of vegetal condition and discrimination of plant species (Nixon et al. 1985), estimation of grassland phytomass production (Everitt et al. 1986), and assessment of soil salinity in agricultural cropland (Everitt et al. 1988). Natural resource managers have also used aerial videography to evaluate fish habitat in streams (Overton and Mussakowski 1983); to monitor aquatic vegetation, spawning areas, and stream dimensions (Mussakowski 1984); to assess rangeland characteristics (Everitt and Nixon 1985); to assess waterfowl habitat in remote areas (Cowardin et al. 1989); and to quantify habitat for shorebirds (Sidle and Ziewitz 1990).

Previous attempts to remotely measure and classify aquatic macrophytes in the Upper Mississippi River have used color aerial photography (Caron et al. 1976; Minor et al. 1977), color-infrared aerial photography (Hagen et al. 1977), and satellite (Landsat) imagery (Werth and Lillesand 1979). These attempts, though largely successful, were hampered by the high cost and limited availability of aerial photographs and satellite imagery. Aerial videography, which had not been used to classify aquatic macrophytes in the Upper Mississippi River, seemed suitable for that use.

We assessed whether aerial videography could consistently distinguish between submergent, floating, and emergent macrophytes and distinguish between species of emergent macrophytes in a backwater lake. We also examined methods for acquiring, analyzing, and interpreting aerial video images of aquatic macrophytes.

Methods

Three overflights were made by Dr. Paul Vohs, Iowa State University, to record video images of Lawrence Lake (181 hectares) in Pool 8 of the Upper Mississippi River during June, July, and September 1990. On the first two flights, a Panasonic digital 5000 camera equipped with an Angenieux lens (1:1.8, f 5.9) was used at 1,036 and 2,134 m above ground (coverage of about 0.7 and 2.6 km^2, respectively) and a Panasonic AG 7400 S-video recorder to obtain the video images of the lake. On the third flight, a Cannon H8 Mark II 8 mm S-video camera (8 to 80 mm zoom; 1/64th of a second shutter speed) was used at altitudes of 610, 1,372, and 2,743 m above ground. Images made at the highest altitude of each flight provided specific locations of video frames obtained at the lower altitudes. During the third flight, 35-mm transparencies of the lake were made from the lowest altitude with a Nikon F2 camera loaded with Ektachrome 100 ASA film.

Computer analysis of the recorded images consisted of passing the S-video signal through a "video" box to separate the red, blue, and green signals into separate rasters, then into a Vision-16 capture board. The capture board was fixed in one of the expansion slots on the microcomputer. We saved the separate rasters and analyzed them simultaneously on a medium resolution screen with the feature map portion of the Map and Image Processing System (MIPS; Micro Image 1990). We analyzed the transparencies, which had been digitized with a Howtek slide digitizer (1,000 dpi) with the MIPS program. By comparing vegetation samples from known locations on the lake, we were able to identify specific pixels as representing specific vegetation types. The MIPS programmed and mapped all representative pixels and calculated their area. The program provided a text file showing the number of separate (discontinuous) incidences of a vegetation type, a total for the type, and a sum of all types.

Before each flight, we placed blaze orange markers (1.2- X 1.2-m X 1.3-cm styrofoam sections) in different vegetation types (stations) and randomly collected a 0.2-m^2 quadrat sample of the vegetation at each station. The markers, arranged in a line at 6- to 7-m intervals, served as resolution targets for video and still photography and as station markers for vegetation sampling. Vegetation sampling involved sorting, drying, and weighing aquatic vegetation by species. The number of stations and markers at each station for the three overflights were as follows: three markers at each of two stations, one marker at each of nine stations, and three markers at each of seven stations. After each flight, we modified the image acquisition protocol to correct deficiencies in station identification and image resolution.

Results

Station markers were not visible on video images made at altitudes above 1,000 m. Consequently, only the images made at or below this altitude provided the spatial resolution of 1 m^2 necessary for marker identification and could be analyzed and used for feature map production. Analysis of the images made during the first overflight included automatic (computer-generated) and manual (operator-assisted) feature mapping. However, the extremely poor resolution of station markers and vegetation types on the automatically generated feature maps made these maps unacceptable for our purposes (Fig. II-1). The automatic feature mapping routine identified very broad patterns such as water and plants but was unable to consistently distinguish between submerged, floating, and emergent vegetation due to "noise" inherent in the video imaging process. The operator-assisted feature mapping procedure was more successful at resolving these vegetation classes and resulted in a more satisfactory feature map (Fig. II-2). Feature maps produced after the second overflight were useless due to our inability to resolve station markers and to uninterpretable video imagery caused by high sun glare during the early afternoon flight.

Modifications (i.e., early morning, lower altitude flights, and three markers per station) to sampling protocols made after the first and second overflights improved our ability to distinguish station markers and vegetation patterns across the lake. Thus, we were able to identify aquatic vegetation as submergent or floating and emergent and produce acceptable feature maps (Figs. II-3 and II-4). In addition to mapping the vegetation classes, the MIPS program calculated the areal coverage of each vegetation type (based on the amount of the spectral value for that vegetation type) in each view. For example, emergent vegetation, including arrowhead (*Sagittaria rigida*), pickerel weed (*Pontedaria cordata*), and bulrush (*Scirpus* sp.), was the most abundant (42%) vegetation type found in the southern end of Lawrence Lake (Table II-1).

Comparisons of vegetation distribution on video-based and transparency-based feature maps with the actual distribution in the field suggest that the MIPS program successfully distinguished submergent macrophytes from floating and emergent macrophytes. Even though the operator-assisted feature maps were assigned different colors to represent floating and other vegetation types, such distinctions could not be consistently made between floating and emergent macrophytes or between the various emergent species present (Figs. II-3 to II-6). For example, emergents such as bulrush and pickerel weed were assigned a spectral value that was indistinguishable from that assigned to floating macrophytes such as the duckweeds, *Wolfia* sp. and *Lemna* sp. In one case, however, transparency-based feature maps accurately reflected station marker locations, whereas video-based feature maps showed two of three station markers that had been placed in turbid open water sites as being situated in vegetation (Figs. II-4 and II-6).

Discussion

Most previous applications of aerial videographic techniques attempted to detect anomalies in monospecific stands of agricultural crops or to quantify the abundance of distinct habitat features. For example, detection applications in monospecific stands included detection of diseased potato plants in a plot (Manzer and Cooper 1982), detection of freeze-damaged citrus leaves (Escobar et al. 1983), and assessment of the degree of weed infestation among agricultural crops (Richardson et al. 1985). Examples of quantified habitat features include numbers of pools and riffles in trout streams (Overton and Mussakowski 1983), estimating number and area of waterfowl habitat (ponds) in remote areas (Cowardin et al. 1989), and quantifying shorebird habitat (sand bars) in a large river (Sidle and Ziewitz 1990). In these examples, the contrasts were relatively straightforward due to the small number of features considered. A few authors did report problems with resolution (Overton and Mussakowski 1983; Everitt et al. 1988; Cowardin et al. 1989) but all were satisfied with their ability to resolve the features of interest.

Our attempts to use aerial videographic techniques to classify aquatic macrophytes in an Upper Mississippi River backwater lake were partially successful. We were able to discriminate between submergent and floating and emergent aquatic vegetation, and to quantify areal coverage. However, our application of the technique did not permit discrimination between the floating and emergent aquatic vegetation. We attribute the less than consistent ability to discriminate the vegetation types in our study site to the complexity of the site, the limited effort of our vegetation sampling, and the resolution limitation of video media.

Our study site was highly complex, containing many features such as open water; submerged, floating, and emergent vegetation; and various combinations thereof. Furthermore, many of these features were interspersed throughout the lake. Our vegetation samples represented a small fraction (0.2 m^2 per station) of the total area in each feature map (about 0.25 km^2), limiting our ability to fully interpret the array of spectra present on feature maps. The high macrophyte diversity encountered in this study is common for aquatic habitats and may indicate some limitations to the application of video technology. Nonetheless, we believe that increased sampling of vegetation at discrete intervals (every 75 m) along transects across the lake, in conjunction with high-resolution video images along that transect with 1/2000th of a second shutter speed, would diminish this problem. The transect approach would provide more representative vegetation samples, which should enhance both assignment of spectral values to specific plants and subsequent plant identification.

Sun glare hampered one of our efforts to apply aerial videography. Sun glare reflecting off the water during early afternoon rendered video images virtually incomprehensible. Closing the camera aperture reduced the amount of light transmitted to the tape, but the resulting loss of resolution was unacceptable. Taking our video images in the early morning, about 0900 h, eliminated this problem. We expect that images taken in the late afternoon would be free of sun glare but would contain shadows. Polarizing filters, and in some instances, modified flight lines, have also been used to alleviate sun glare interference on aerial videographic images (Overton and Mussakowski 1983).

Feature maps made from digitized transparencies offered better resolution than did feature maps made from video images. Nonetheless, we experienced difficulty in discriminating between floating and emergent vegetation on transparency-based feature maps. In this instance, we attribute our inability to discriminate between these two classes of vegetation to less than adequate sampling of vegetation, not to limitations related to the transparency medium. We anticipate that combining the suggested protocol for transect sampling of vegetation with a lower flight altitude would allow discrimination between floating and emergent vegetation, and among emergent species. Other researchers have also found that digitized 35-mm color transparency is preferable to digitized video images for evaluating small-scale study areas (John Sidle, USFWS, personal communication).

The reduced resolution of aerial videography relative to other remote sensing techniques may limit its application, yet the ability to quickly assess large areas is a major advantage of this technique. However, test flights with a video camera over intended study sites should be made to determine if the desired level of discrimination is attainable. We believe that 35-mm color transparencies are preferable to video imagery for assessing smaller areas because larger areas would necessitate more transparencies. Handling large numbers of transparencies may be ponderous and increase the time needed for digitization, delaying feature map production.

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Table II-1. Areal coverage of habitat components determined from digitized video images of the lower portion of Lawrence Lake (Pool 8, Upper Mississippi River) September 1990.

Feature type	Area (m^2)	Percent of total area
Dark emergent vegetation	45,681	15.3
Medium emergent vegetation	61,857	20.7
Light emergent vegetation	18,795	6.3
Submergent vegetation	18,302	6.1
Floating vegetation	47,797	15.9
Land	37,477	12.5
Roads	4,755	1.6
Water	64,248	21.5
Station markers	28	<0.1

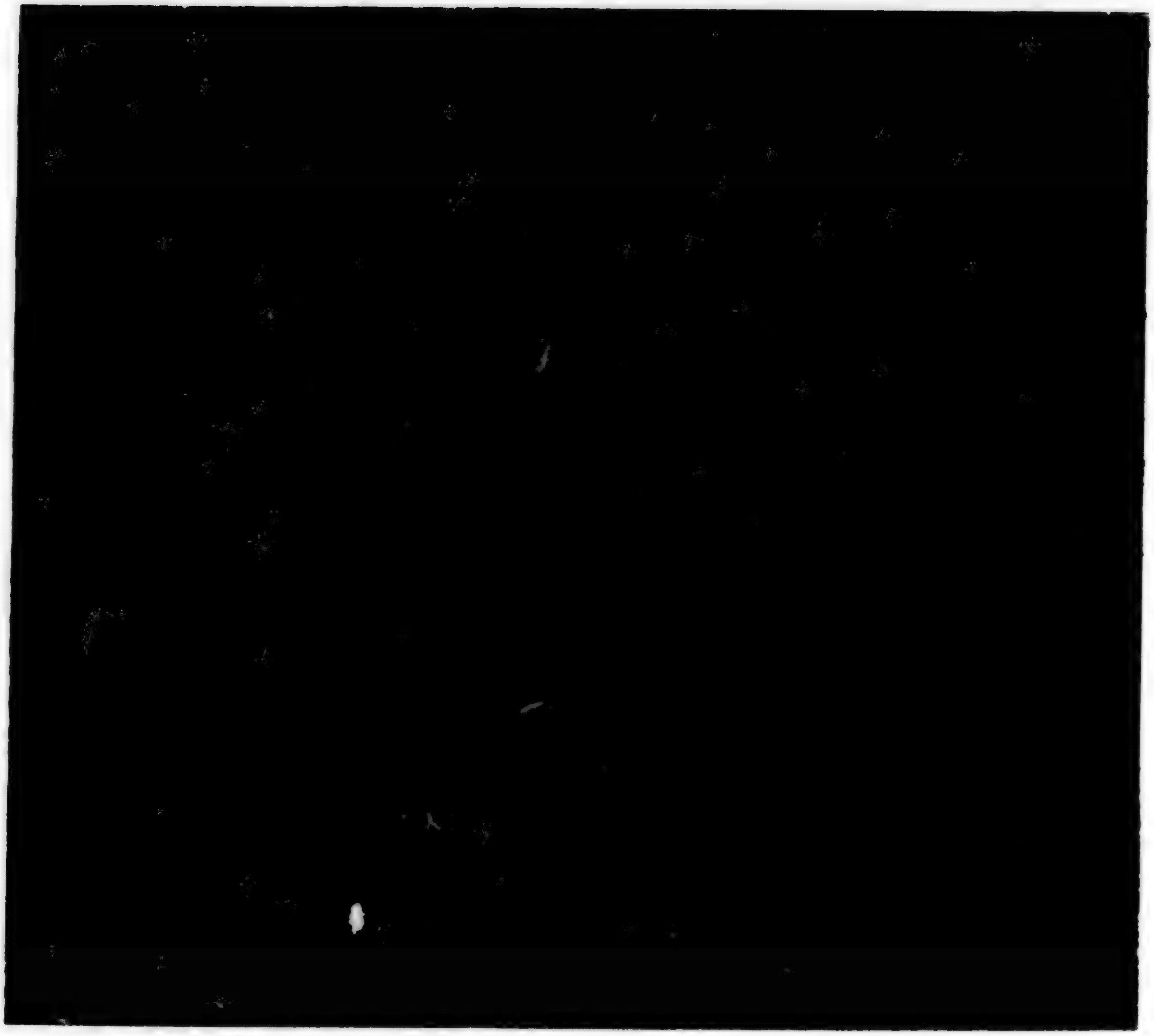

Figure II-1. Computer-generated feature map (0.7 km^2 area) from the June 1990 overflight of Lawrence Lake (Pool 8, Upper Mississippi River).

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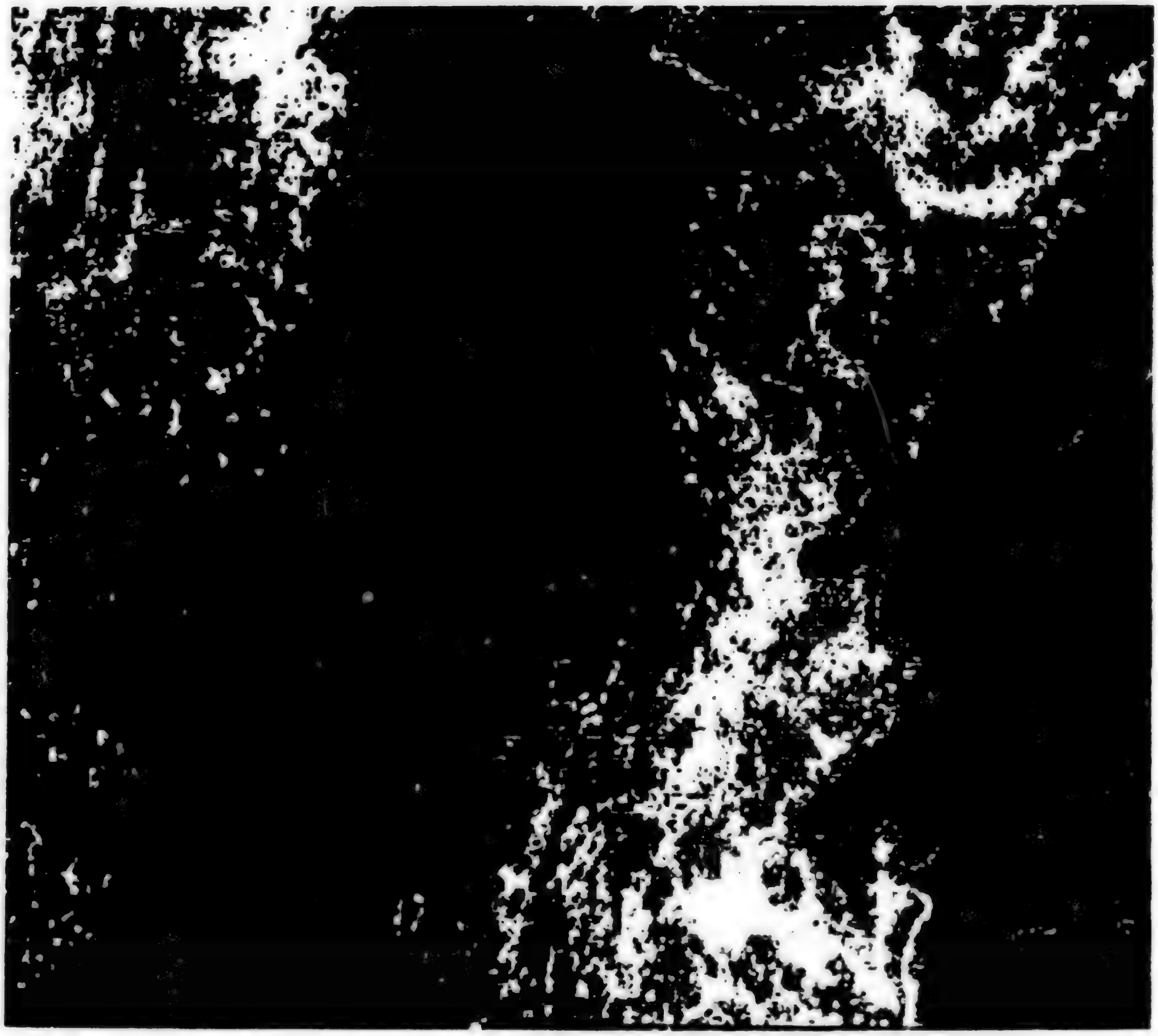

Figure II-2. Operator-assisted feature map (0.7 km^2 area) from the June 1990 overflight of Lawrence Lake (Pool 8, Upper Mississippi River). Red areas indicate station markers.

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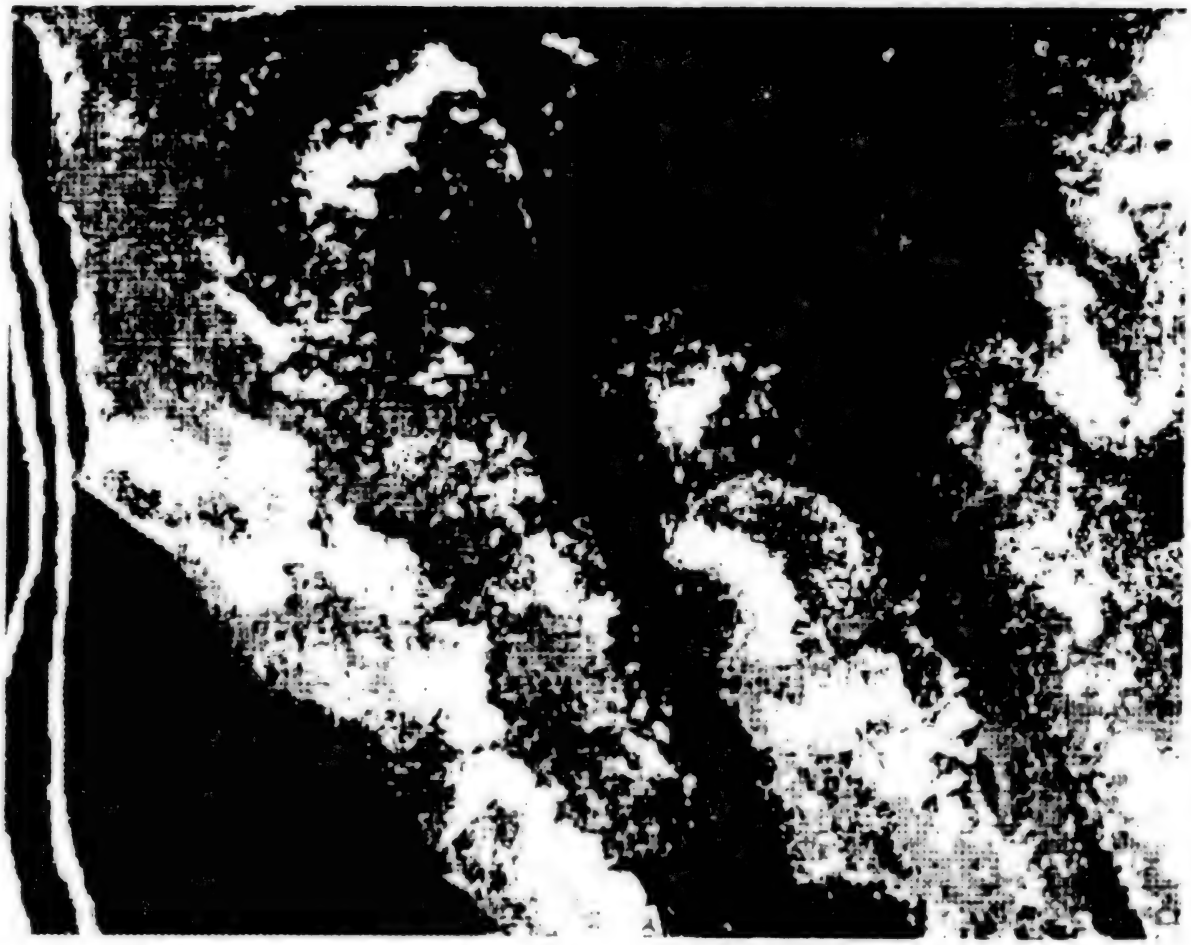

Figure II-3. Feature map produced from digitized video imagery made during the September 1990 overflight of Lawrence Lake (Pool 8, Upper Mississippi River). The map includes about 0.3 km^2 of the lower portion of the lake. Color key: white = roads; purple = land; blue = open water; yellow = floating vegetation; green shades = emergent and submergent vegetation, red = station markers.

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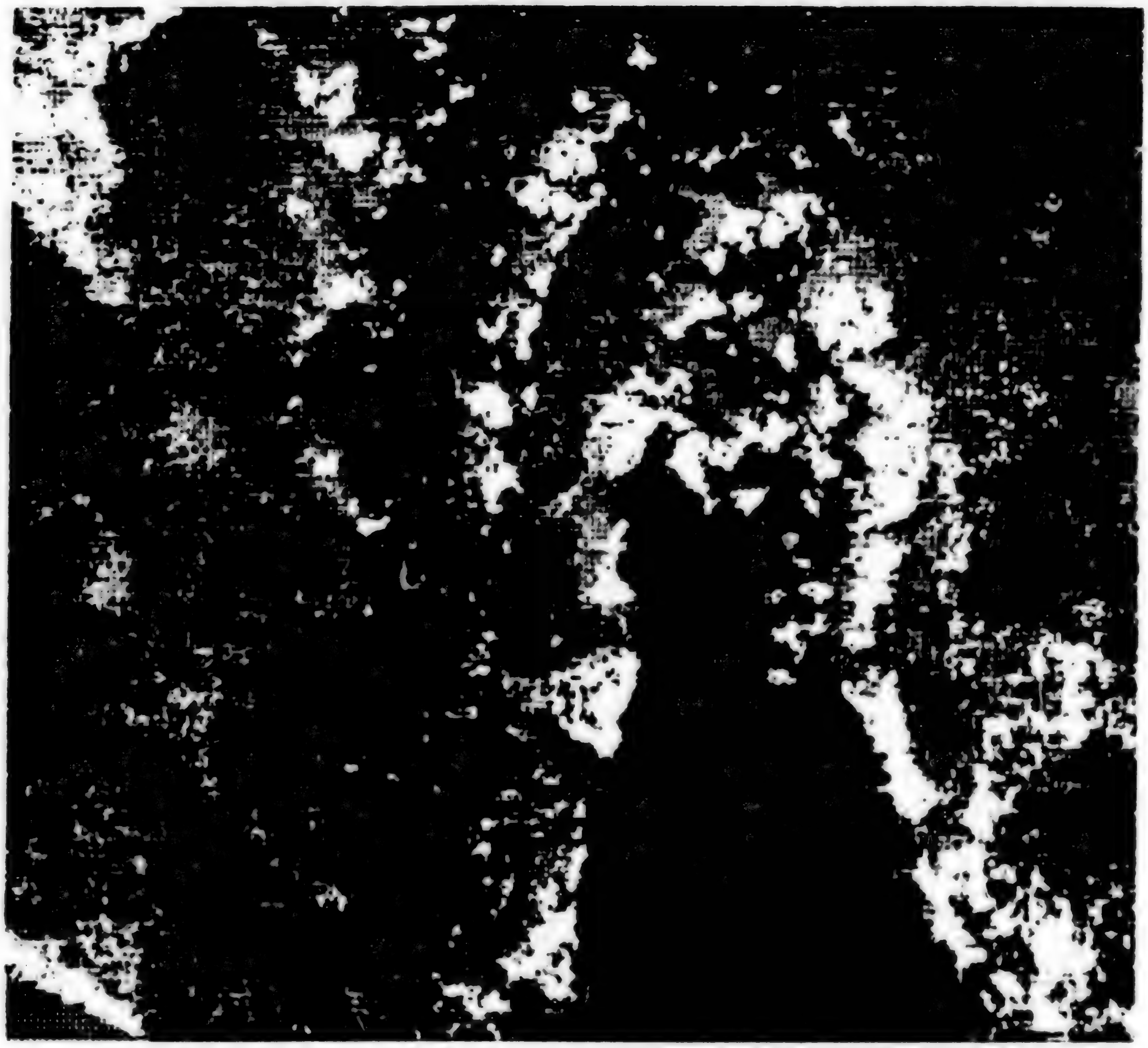

Figure II-4. Feature map produced from digitized video imagery made during the September 1990 overflight of Lawrence Lake (Pool 8, Upper Mississippi River). The map includes about 0.3 km^2 of the upper portion of the lake. Color key: White - roads; purple - land; blue - open water; yellow - floating vegetation; green shades - emergent and submergent vegetation, red - station markers.

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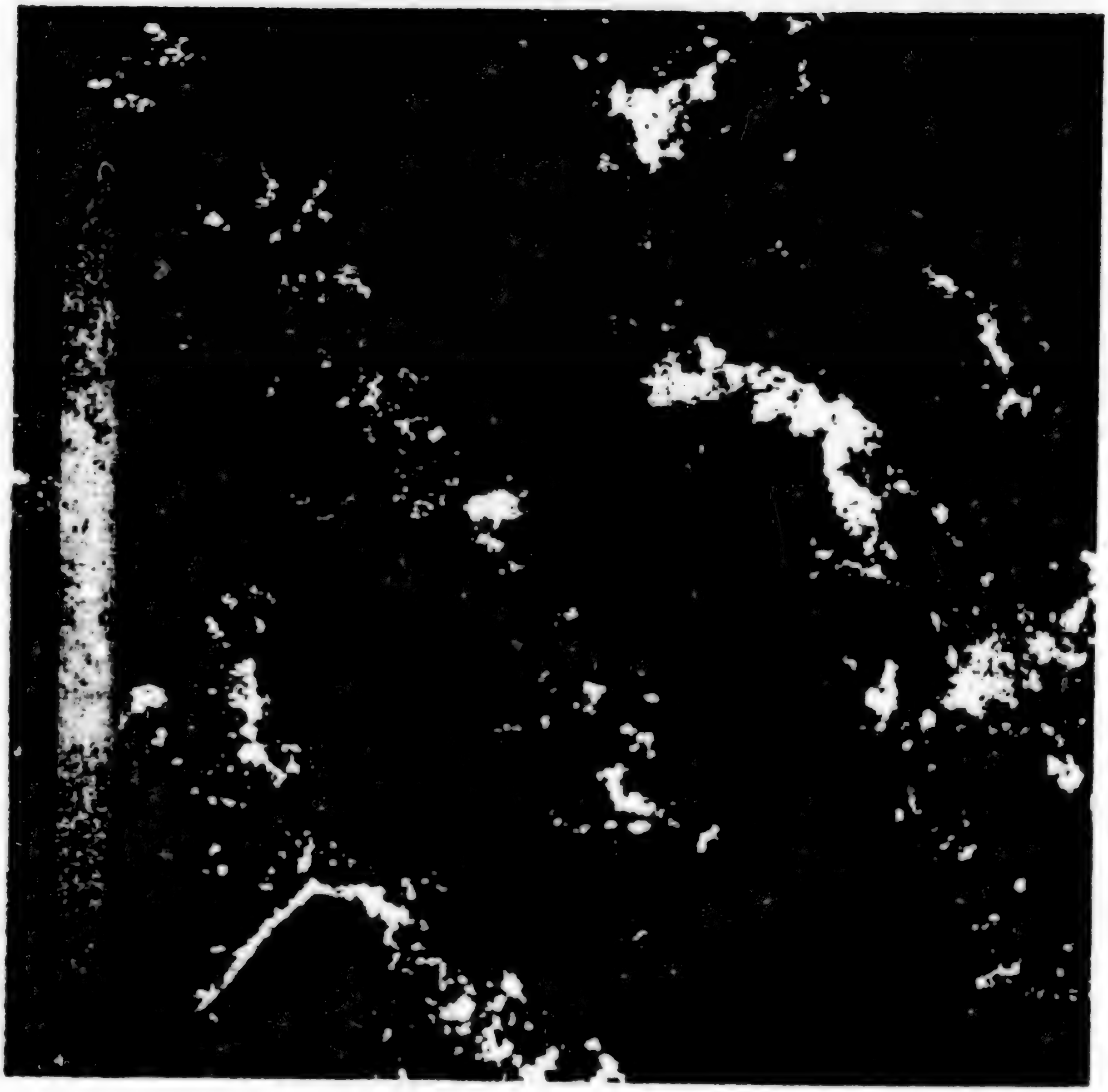

Figure II-5. Feature map produced from digitized color transparencies made during the September 1990 overflight of Lawrence Lake (Pool 8, Upper Mississippi River). The map includes about 0.08 km^2 of the lower portion of the lake. Color key: blue = open water; yellow = floating vegetation; green shades = emergent and submergent vegetation, red = station markers.

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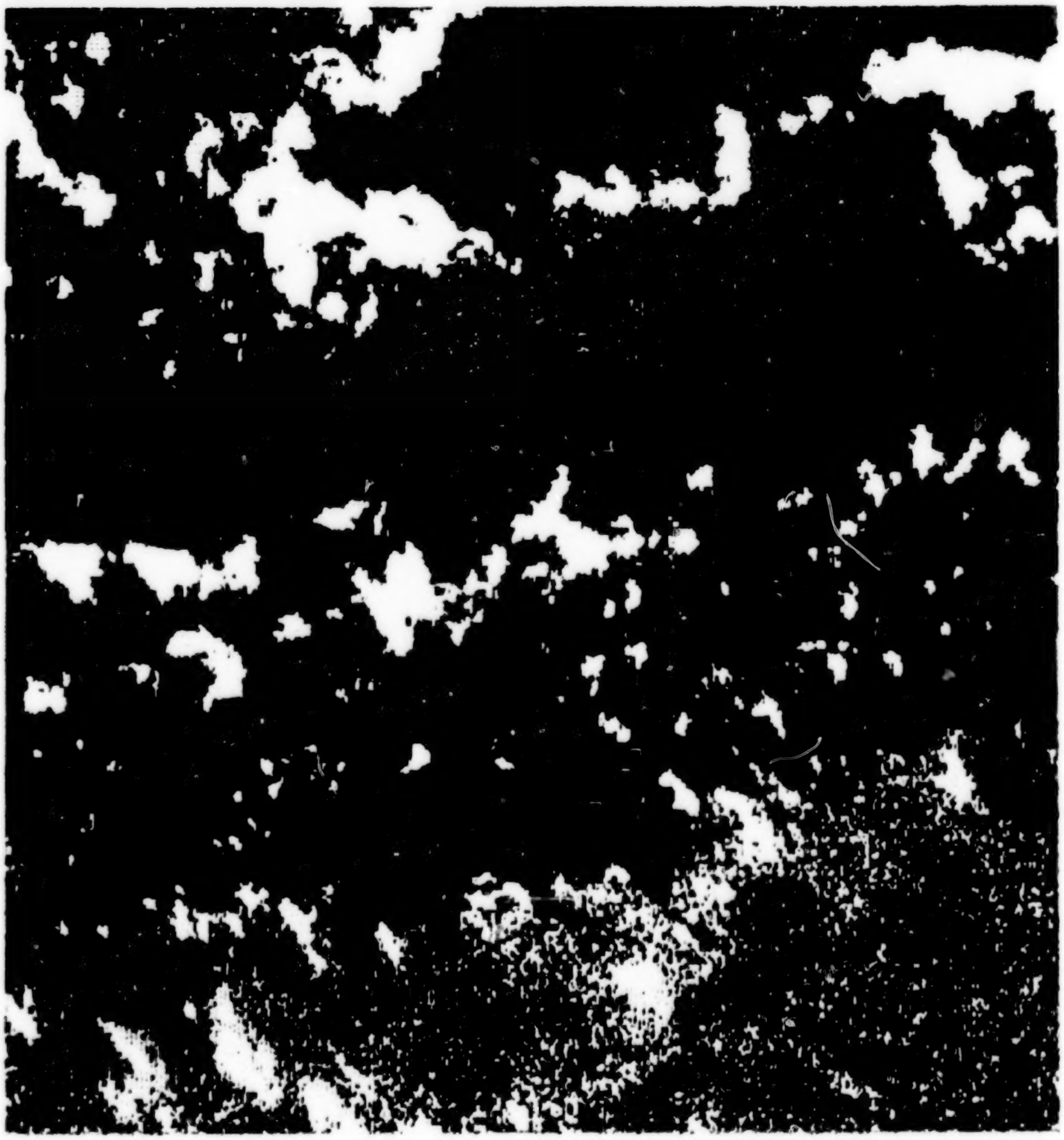

Figure II-6. Feature map produced from digitized color transparencies made during the September 1990 overflight of Lawrence Lake (Pool 8, Upper Mississippi River). The map includes about 0.08 km^2 of the upper portion of the lake. Color key: blue = open water; yellow = floating vegetation; green shades = emergent and submergent vegetation, red = station markers.

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REPORT DOCUMENTATION PAGE

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1. AGENCY USE ONLY (Leave blank)

2. REPORT DATE

April 1994

3. REPORT TYPE AND DATES COVERED

4. TITLE AND SUBTITLE

Factors Limiting the Distribution of Larval and Juvenile Fishes in Vegetated Habitats of the Upper Mississippi River

5. FUNDING NUMBERS

6. AUTHOR(S)

Michael R. Dewey and Cecil A. Jennings

7. PERFORMING ORGANIZATION NAME AND ADDRESS

National Biological Survey
National Fisheries Research Center
P.O. Box 818
La Crosse, Wisconsin 54650-0818

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

National Biological Survey
Environmental Management Technical Center
575 Lester Avenue
Onalaska, Wisconsin 54650

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

94-S005

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Release unlimited. Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

We studied the use that young fishes make of vegetated and nonvegetated habitats in Lawrence Lake (Pool 8, Upper Mississippi River). Habitat use was both extensive and variable. Fish were found in all portions of the macrophyte beds. Backwater macrophyte beds both near to and distant from the main channel of the Mississippi River displayed similar patterns of habitat use. The open water site was used principally by gizzard shad and unidentified Cyprinidae. Habitat use in macrophyte beds with differing vegetation densities in Lawrence Lake was probably influenced by multiple factors. Physical and chemical microhabitat data explained little of the variation in catch in light traps. Two-stage sampling analyses indicated that when fish density is highly variable, sampling at many stations (one sample per station) is needed to assess habitat use in relation to vegetation density and species complexity. We evaluated several gears for both quantitative and nonquantitative sampling of juvenile fishes in vegetated habitats. From July through September, we conducted field tests to compare catches from light traps, fyke nets, hoop nets, gill nets, and minnow traps. Three quantitative sampling gears, an electrofishing frame, a drop net, and a pop net, were used. The electrofishing frame was modified with a drop-net mechanism to assess the capture efficiency of the electrofishing device and to serve as a drop net. Light traps, which principally sampled larval fishes, were effective in vegetated habitats. Catches with all three quantitative gears were dominated by juvenile bluegills. The electrofishing frame caught significantly fewer fish in turbid vegetated areas than the drop and pop nets, due to difficulty in observing and netting stunned fish. Capture efficiencies with the electrofishing frame were higher in clear nonvegetated areas (mean 80%) than in turbid vegetated areas (mean 5%). The drop net and pop net yielded similar catches in number and species composition. With the drop net, extensive seining (8-10 hauls) was required to collect all fish within the net enclosure. However, use of a removal method to estimate absolute catch decreased seining effort to three or four hauls, more comparable to that of the pop net. We recommend either drop nets or pop nets for quantitative sampling. Replicated tests with nonquantitative sampling gears were conducted to evaluate the effectiveness of fyke nets, hoop nets, small-mesh gill nets, and minnow traps in submergent vegetation and the effectiveness of small-mesh gill nets and hoop nets in an open water habitat. Of the nonquantitative gears tested, fyke nets produced the greatest numbers and species of fish. In open water, replicated sets of small-mesh gill nets and hoop nets showed that the gill nets were effective for capturing gizzard shad and golden shiners.

14. SUBJECT TERMS

larval fish, backwaters, sampling gear, microhabitat, Upper Mississippi River, aerial videography

15. NUMBER OF PAGES

Part I, 61pp.; Part II, 19 pp.

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT

Unclassified

18. SECURITY CLASSIFICATION OF THIS PAGE

Unclassified

19. SECURITY CLASSIFICATION OF ABSTRACT

Unclassified

20. LIMITATION OF ABSTRACT

The Long Term Resource Monitoring Program (LTRMP) for the Upper Mississippi River System was authorized under the Water Resources Development Act of 1986 as an element of the Environmental Management Program. The mission of the LTRMP is to provide river managers with information to maintain the Upper Mississippi River System as a viable large river ecosystem given its multiple-use character. The LTRMP is a cooperative effort by the National Biological Survey, the U.S. Army Corps of Engineers, and the states of Illinois, Iowa, Minnesota, Missouri, and Wisconsin.

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